The Indian Mackerel

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Marine Fisheries P.O.

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C O N T E N T S

PREFACE

The present Bulletin deals with the biology and fishery of the Indian Mackerel, *Rastrelliger kanagurta* (Cuvier) which contributes much to our national economy, ranking next to the prawns and the oil sardine, comprehensive accounts of which have appeared in Bulletins 14 and 16 respectively. Pioneering work on the fishery aspects of the mackerel has been carried out in the first half of this century by the Department of Fisheries of the erstwhile Madras State, but by far a good deal of very useful information has been added since 1947 when this Institute initiated investigations on the commercial groups contributing to the marine fishery resources of India. In the light of our increased knowledge of this fish, our earlier concepts regarding its age, rate of growth, breeding behaviour etc. have been modified to a certain extent. With the recorded occurrence of a distinctly separate species, *R. brachysoma* (Bleeker) in the Andaman region and with comprehensive accounts of the morphometric and meristic characters of this species and *R. kanagurta*, our knowledge of the taxonomy of the genus has appreciably increased. The mackerel studies are of international importance as the same species occur on other coasts as well, contributing to the fisheries wealth in many countries in the Indo-Pacific Region.

All information available on the fishery and biology of the Indian mackerel has been compiled and presented here so that it may be easily accessible to the interested workers on the subject. I am very sincerely thankful to my colleagues, Messrs. S.K. Banerji, K. Virabhadra Rao, G. Venkataraman, K.V. Narayana Rao and Dr. V. Balakrishnan who have collaborated with me and brought out this useful, comprehensive compilation work. My thanks are also to all those who have helped in the preparation of this Bulletin.

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Mandapam Camp,
Dec. 4, 1970.

I. INTRODUCTION

By

R.V. Nair

(Central Marine Fisheries Research Institute, Mandapam Camp)

I. INTRODUCTION

R.V. Nair

The mackerel Rastrelliger kanagurta (Cuvier) is a pelagic shoaling fish widely distributed in the Indo-Pacific region and its fishery nowhere else is of such high magnitude as on our coasts. Being a much esteemed table-fish which is greatly in demand, its fishery is an important source of livelihood to those engaged in fishing and dependent industries. The bulk of the catches is obtained on the west coast between Cape Comorin and Ratnagiri. The landings of mackerel on the east coast in general are low, but in some parts of Tamil Nadu, Andhra and Orissa they are often heavy. In the past two decades the annual all-India mackerel landings had exceeded one lakh metric tons during 1951, 1958 and 1960; in the leanest of the years i.e. in 1956 the catch was only a little over 16 thousand metric tons; the annual mackerel catch in the total marine fish landings varied from 2.29% to 19.65% in the said period. Such wide fluctuations, noticed in the earlier years also, drew the attention of the fishery workers since the beginning of this century.

In almost the first half of this century valuable contributions have emerged (Hornell, 1910b, 1917, 1924; Devanesan and John, 1940; Devanesan, 1942; Chidambaram, 1944; Chidambaram and Devidas Menon, 1945; Chari, 1948; Chidambaram et al., 1952) as a result of the investigations carried out by the Department of Fisheries of the then composite Madras State on certain aspects of mackerel biology, regional fishery trends and the prevailing methods of exploitation; some of these and other accounts which appeared in the Department's periodical reports deal also with problems related to transport, marketing, preservation and processing of the mackerel landings.

With the establishment of the Central Marine Fisheries Research Institute in 1947, a great impetus was given to the progress of research on problems affecting the mackerel fishery. The initiation of the survey

programme to collect fisheries statistics on an all-India basis at the Institute has helped furnishing reasonably accurate landing figures in all zones and in all seasons. Biological studies on mackerel were also commenced at the same time. During the fifties and sixties quite a large number of contributions have appeared on varied aspects, such as taxonomy and distribution, age and rate of growth, food and feeding in relation to quantitative and qualitative abundance of planktonic elements, maturity, fecundity and spawning periodicity, distribution of juveniles in time and space, exploitation, catch in terms of effort by fishing units, stock assessment and population dynamics and the probable ecological factors determining the fishery fluctuations. While these investigations have undoubtedly augmented our knowledge of the mackerel and its fishery, they have also shown very pointedly the lacunae in our findings, where further work is urgently needed.

Two species of Rastrelliger occur on our coasts, viz. the Indian mackerel R. kanagurta (Cuvier) and the short-bodied mackerel R. brachysoma (Bleeker), the former is the species which supports the mackerel fishery of India and is dealt with here in detail; the latter which is reported from Andamans is also described, but only from the point of view of its systematics.

An attempt is made to bring together and present here the facts we know and the concepts we hold regarding the mackerel fishery in the light of a critical assessment of the work so far carried out. The purpose of this bulletin is to arouse an awareness in the scientific workers of the magnitude of the problems involved and set them thinking on the lines to be adopted for solving them.

II. IDENTITY

By

K. Virabhadra Rao

(Central Marine Fisheries Research Institute, Mandapam Camp)

II. IDENTITY

K. Virabhadra Rao

2.1 TAXONOMY

The family Scombridae (under the order Perciformes of sub-class Actinopterygii) comprises four subfamilies viz., Gasterochismatinae, Thunninae, Scomberomorinae and Scombrinae. The first subfamily includes just one member, Gasterochisma melampus Richardson, popularly known as the butterfly mackerel which has a southern and disjunct distribution, occurring on coasts of South Africa, New Zealand, Australia and Argentina. Thunninae includes a large assemblage of species, called tunnies coming under the genera Auxis Cuvier, Cybiosarda Whitley, Sarda Cuvier, Gymnosarda Gill, Thunnus South, Allothunnus Serventy, Orcynopsis Gill, Katsuwonus Kishinouye and Euthynnus Jordan and Gilbert. The genus Thunnus comprises several subgenera, viz., Thunnus S.Str., Parathunnus Kishinouye, Kishinoella Jordan and Hubbs and Neothunnus Kishinouye. Scomberomorinae has the seer fishes under the genus Scomberomorus Lacepede and the Wahoo under Acanthocybium Gill. The subfamily Scombrinae includes the chub mackerels or the true mackerels and the double-lined mackerel under the genera Scomber Linnaeus, Rastrelliger Jordan and Starks and Grammatorcynus Gill. Most members of these four subfamilies are well distributed in the Indo-Pacific region. Some, however, are restricted in their distribution to temperate regions only as Scomber scombrus, Orcynopsis unicolor and Allothunnus fallai Serventy. The genus Rastrelliger has two valid species i.e. R. kanagurta (Cuvier) and R. brachysoma (Bleeker) occurring in the seas around India, the former being by far the commonest and most abundant mackerel species in this region.

2.1.1 Definition

Phylum VERTEBRATA
Subphylum Craniata
Superclass Gnathostomata
Series Pisces
Class Teleostomi
Subclass Actinopterygii
Order Perciformes
Suborder Scombroidei
Superfamily Scombroidae
Family Scombridae
Genus Rastrelliger Jordan and Starks 1908
Species R. kanagurta (Cuvier) 1817; and
R. brachysoma (Bleeker) 1851

2.1.2 Description

Genus Rastrelliger Jordan and Starks 1908

The following is the description of the genus Rastrelliger as given by Jones and Silas (1964a): "Body compressed from side to side; body and cheek covered with small scales, eyes with well developed adipose eye-lid, mouth large, maxillary reaching nearly vertical below posterior edge of eye; teeth small, present in jaws; vomer and palatine edentulous; gill rakers long, numerous and feather-like and visible when mouth is opened. Spinous first dorsal and soft rayed second dorsal separated by distance equalling length of base of former; anal devoid of spines; five or six dorsal and anal finlets; pectorals short with broad base; pelvics with a spine and five rays; caudal deeply forked."

The nominal species under the genus are known to occur in the tropical belt of the Indian Ocean, extending in range from the east coast of South Africa to North Australia and as far as the Micronesian and Polynesian Islands.

Scomber being very similar to Rastrelliger in external appearance it is considered necessary to point out the salient characters of similarity and distinction between the two genera. In both there is an adipose eye-lid, the corselet is poorly developed, the inter-pelvic process is single and small and the caudal peduncle has only two small keels on each

side. In Scomber the teeth are present on the vomer and the palatine, the gill rakers are fewer (generally less than 35 on the lower limb of the first branchial arch) not very long and not visible in the gape of the mouth, body is stout and circular in cross section, its depth less than the length of the head and an osseous stiff anal spine present where-as in Rastrelliger the vomer and palatines are edentulous, gill rakers larger in number (generally more than 35 on the lower limb of the first branchial arch) protruding into the buccal cavity and clearly visible when the mouth is open, body is laterally compressed and anal spine is wanting (Fraser-Brunner, 1950; Jones and Silas, 1964a;Collette and Gibbs, 1963).

For a long time, the generic name Scomber was used for including the species now referable under Rastrelliger also (Cuvier, 1817; Ruppell, 1835; Bleeker, 1856; Day, 1870). The separation of Rastrelliger brings the recognisable species of Scomber occurring in the Indo-Australian Archipelago to just two, they being S. australasicus Cuv. & Val. and S. japonicus Houttuyn. De Beaufort (1951) recognised two species viz. S. australasicus and S. janesaba Bleeker, but the latter is now known to be synonymous with S. japonicus. The validity of the generic name Pneumatophorus for those members of Scomber having the air-bladder, as distinct from Scomber proper without that structure is doubted (Jones and Silas, 1964a). There is a great deal of confusion regarding the number of valid species under Scomber. Fraser-Brunner (loc.cit.) has recognised only two distinct world species under Scomber viz., S. scombrus Linnaeus and S. japonicus Houttuyn, the former occurring in the Atlantic Ocean and the Mediterranean Sea (including the adjoining Black Sea) and the latter having a much wider distribution in the Atlantic, Indian and Pacific Oceans. Matsui (1967), reviewing the mackerel genera under Scomber and Rastrelliger has come to the conclusion that three valid species under Scomber are recognisable, they being S. scombrus, S. australasicus and S. japonicus and that the many similarities between them warrant their being placed in the same genus and that there is no reason to recognise Pneumatophorus for the two latter species. He, however finds that one of the Philippine mackerels previously regarded as S. australasicus (Syn. P. australasicus) by de Beaufort (1951) and Manacop (1956) is a new species of Rastrelliger which he has named R. faughni. In this species

the vomer and the palatine are edentulous as in other members of Rastrelliger, but the gill rakers are short as in Scomber. In a few osteological characters also like the rudimentary anal spine and in the characteristic shape of interhaemal bones and the hyoid, R. faughni shows close resemblance to other members of Rastrelliger.

2.1.3 Key to the identification of mackerel species

There is much of overlapping in the characters of R. kanagurta and R. brachysoma, but the prominent distinction between the two lies in respect of relation between head length and the greatest depth of the body. The following is the key to the identification of the mackerel and mackerel-like fishes occurring in the Indian coastal waters including the Andaman Sea (Abridged, after Jones and Silas, 1964 b):

1 a. Side of body with two lateral lines; gill rakers on lower limb of outer gill arch generally not exceeding 16

.. .. Grammatorcynus bicarinatus (Quoy & Gaim.)

1 b. Side of body with a single lateral line; gill rakers on lower limb of outer gill arch exceeding 20 2

2 a. Vomer and palatine toothed; osseous and moderately stiff anal spine present

.. Scomber japonicus Houttuyn

2.b. Vomer and palatine edentulous; osseous stiff anal spine absent 3

3 a. Greatest height of body 23-27% of fork length; length of head about equal to or more than the greatest depth of body; snout pointed; anterior margin of spinous dorsal dusky; dark longitudinal stripes often clear on upper half of body

.. Rastrelliger kanagurta (Cuvier)

3 b. Greatest height of body 28 to 34% of fork length; length of head distinctly smaller than the greatest depth of body; snout short, bluntly rounded; posterior margin of spinous dorsal conspicuously black; body without longitudinal stripes

.. R. brachysoma (Bleeker)

2.2 NOMENCLATURE

2.2.1 Valid scientific names

A. Rastrelliger kanagurta (Cuvier)

Russell(1803) in his account on the fishes of Visakhapatnam figured and described the Indian mackerel as "kanagurta" after its vernacular local name (Telugu). He did not follow the conventional binomial nomenclature, but there is no ambiguity about the description and the figure having been well drawn, doubt does not arise about its identity. Cuvier in 1817 (Regene Animal, 2: 313) adapted this name and described the form as Scomber kanagurta. Subsequently Cuvier himself has used the name as S. canagurta in 1829 (Regene Animal 2nd Edn. 2: 197) and S. kanagurta in 1831 (Histoire Naturelle des Poissons, 8: 49). Since the generic name Rastrelliger of Jordan and Starks in Jordan and Dickerson (1908) has come to be adopted for some of the forms originally referred to under Scomber, the species is now recognised under the name R. kanagurta.

B. Rastrelliger brachysoma (Bleeker)

De Beaufort (loc. cit.) has recognised three species of Rastrellier occurring in the Indo-Australian Archipelago, they being R. kanagurta (Cuvier), R. brachysoma (Bleeker) and R. neglectus (Van Kampen). In the first the head is longer than high and the body is slender whereas in the other two which are considered synonymous, the head is as long as high and the body distinctly deep. The specific name brachysoma of Bleeker (1851) has priority over neglectus of Van Kampen (1907) and hence the former is the valid name.

The following are the descriptions of adults of two species of Rastrelliger kanagurta and R. brachysoma:

Rastrelliger kanagurta (Cuvier 1817) (Fig.1 A&B)

D^1. 8-10, D^2. 1/11 + V-VI, A. 1/11 + V-VI, P^1. 19-22, P^2. 1/5, C. 24, L.l. 128-150, L.tr. 10/28, Vert. 13/16.

Length of head $3\frac{3}{4}$ to $4\frac{1}{4}$, caudal $4\frac{3}{4}$ to 5, height of body 4 to 4 2/3 in total length. Length of head about equal to height of body. Head length longer than its height. Eye with thick adipose eye-lid, its diameter 4 to $4\frac{1}{2}$ times in length of head and 1.53 in snout. Snout pointed and a little less than the interorbital space. Mouth oblique, lower jaw a little larger than the upper, cleft of mouth deep, maxilla reaches to below the hind edge of the eye. Teeth minute and pointed in single series in both jaws, often disappearing with age. Vomer and palatine edentulous. Gill-rakers moderately long feathery and with pointed tips, 17 to 24 on the upper and 33 to 45 on the lower branch of the first gill arch. Dorsal spines weak. First dorsal spine shorter than the second and last spine small and feeble. Finlets arise behind the second dorsal and the anal fins, the upper and the lower ones similar and opposite, arranged in pairs. Anal insertion a little behind origin of second dorsal. Pectoral triangular and pointed, less half the length of head. Scales ctenoid, broader than long, those around pectoral base the largest, scale spines prominent and about 30. Caudal deeply forked, lobes pointed. Air vessel present.

Coloration.- Body greenish blue above and silvery yellow on belly and at the sides. About three grayish longitudinal stripes above the lateral line present. A row of about 16 irregular blotches below the dorsal fin on the back. A dark blotch on the body behind the pectoral base visible externally through the translucent pectoral fin. Two or three black spots along the base of the spinous dorsal. Dorsal fins yellow, with tips and outer margin grayish. Pectoral yellow. Ventral and anal fins hyaline and faintly dotted when fresh. Caudal yellow, dusky along the margin and extremities.

Colour and markings variable with age. In large specimens several dark longitudinal bands on the upper half of the body prominent and the uppermost of them broken up into blotches. A few golden yellow bands along and below the lateral line. Small juveniles have prominent, small roundish dots along the upper half of the back.

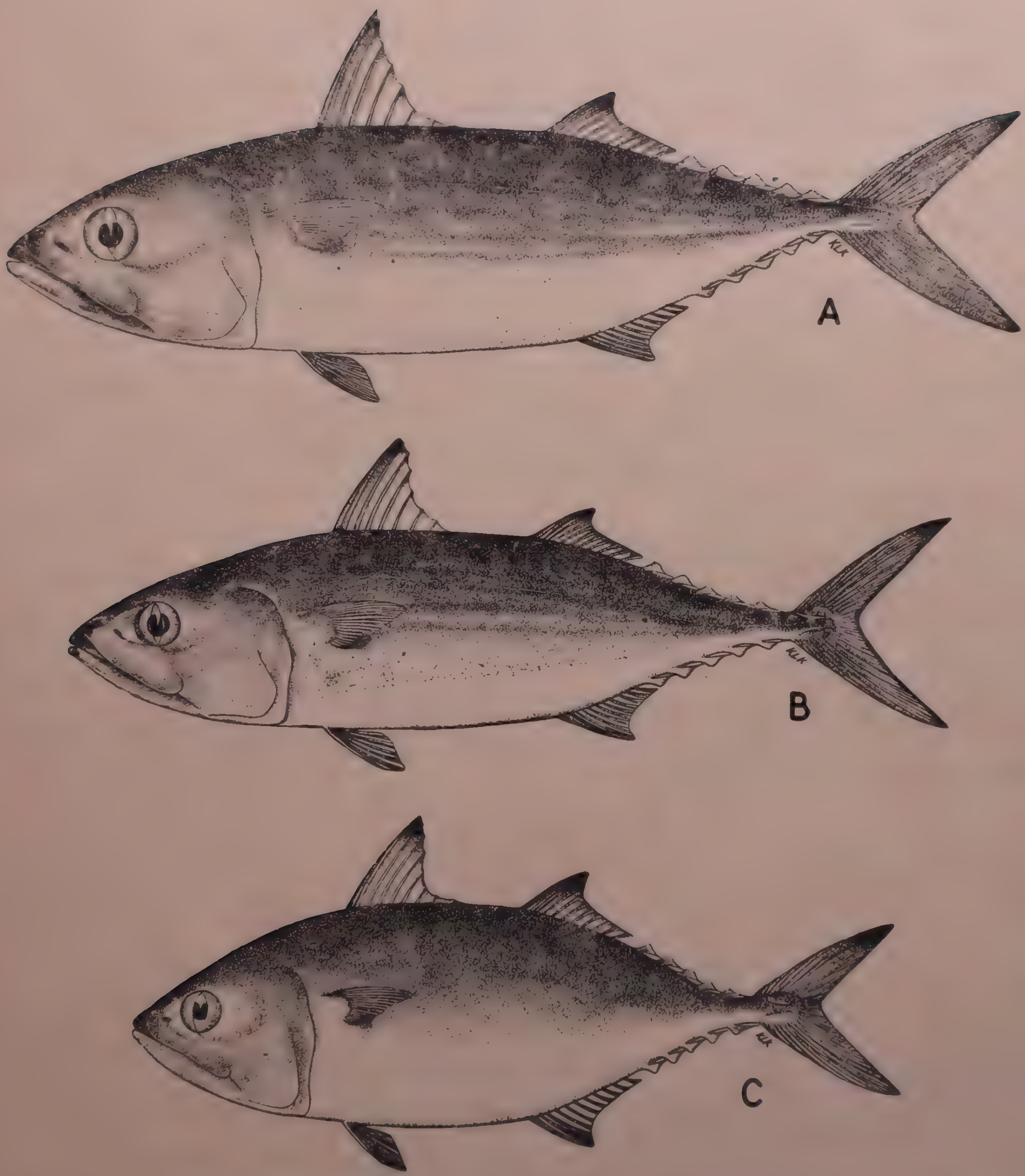

Fig. 1. A. *Rastrelliger kanagurta* (Cuvier) from Andamans; B. *R. kanagurta* (Cuvier) from Calicut; C. *R. brachysoma* (Bleeker) from Andamans.

Rastrelliger brachysoma (Bleeker 1851) (Fig.1 C)

D^1. 8-10, D^2. 1/11 + V-VI, A. 1/11 + V-VI, P. 22, V. 1/5, C. 21, L.l. 135, Vert. 31-32.

Head $3\frac{3}{4}$, caudal $5\frac{1}{4}$ and height of body 3 2/3 in total length. Eye diameter 4 1/3 in head length, 1.1 to 1.4 in snout and equal to inter-orbital space. Preorbital 4/7 of the head. Head as long as high. Length of head much less than the greatest depth of body. Mouth oblique, lower jaw a little longer. Maxilla reaches a little beyond the hind border of the eye. Teeth in a single series minute and pointed in both the jaws, but absent on vomer and palatine. Gill rakers longer and more numerous than in R. kanagurta, 16 to 24 in upper limb and 34 to 45 on the lower limb of the first branchial arch. Dorsal spines weak. Arrange-ment of finlets as in R. kanagurta. Pectoral half as long as head, caudal deeply forked. Scales ctenoid, squarish.

Coloration.- Bluish green above and silvery with yellowish tinge below. Distinct dark longitudinal bands are absent. Often one or two rows of black spots along the back present. Distal border of spinous dorsal conspicuously black. A faint dark blotch behind the pectoral base. When fresh two glistening whitish spots visible on the head above and behind each eye.

2.2.2 Synonyms

A. Rastrelliger kanagurta (Cuvier) 1817

Scomber kanagurta Cuvier, Regene Animal, II, 1817, p. 313 (footnote); Ruppell, Atlas Reise N. Afrika. Fishe des rothen Meeres, 1828, p. 93; Cuvier and Valenciennes, Hist. Nat. Poissons, VIII, 1831, p. 49; Gunther, Fishe der Sudsee II, 1876, p. 140; Macleay, Proc. Linn. Soc. New S. Wales, IX, 1884; Jordan and Evermann, Proc. U.S. Nat. Mus. XXV, 1902, p. 336; Fowler, Proc. Acad. Nat. Sc. Philadelphia, LVI (1904), 1905, p. 757; Fowler & Bean, Proc. U.S. Nat. Mus., LXII, 1922, p. 18.

Scomber canagurta Cuvier, Regene Animal, ed 2, II; 1829, p. 197 (footnote).

Scomber chrysosoma Ruppell, Neue Wirbelthiere, Fische des Rothen Meeres, 1835, p. 37.

Scomber loo Cuvier and Valenciennes, Hist. Nat. Poissons, VIII, 1831, p. 52; Bleeker, Verh. Bat. Gen. XXIV, Bidjr. Kennis Makreel, 1852, p. 35; Kner, Novara Exp. Fische I, 1865-67, p. 142;

Scomber microlepidotus Ruppell, Neue Wirbelthiere Fische des Rothen Meeres, 1835, p. 38; Day, Fishes of India, Pt. I, reprinted 1958, p. 250; Jordan and Seale, Bull. Bur. Fish., XXVI (1906) 1907, p. 12; Evermann and Seale, ibid., p. 61; Blegvad, Danish Sc. Inv. Iran, Pt.III, 1944, p. 159.

Scomber moluccensis Bleeker, Acta Soc. Indo-Neerl., 1, 1856, p. 40; M. Weber, Siboga Exp. Fische, 1913, p. 400.

Scomber reani Day, Proc. Zool. Soc. London, 1870, p. 690.

Scomber lepturus Agassiz, Pisces celebes, 1874, Tab.2,

Rastrelliger brachysoma (nec. Bleeker) Jordan and Dickerson, Proc. U.S. Nat. Mus. XXXIV, 1908, p. 190.

Rastrelliger chrysozonus Kishinouye, J. Coll. Agric. Tokyo, VIII, No.3, 1923, p. 406; Manacop, Philippine J. Fish., 1958, 4(2): 92.

Rastrelliger serventyi Whitley, Austr. Zool., X, 1944, 252-273.

Rastrelliger microlepidotus Barnard, Ann. S. Afric. Mus. XXI, Pt.2, 1927, p. 796.

Rastrelliger kanagurta Jordan and Starks, Ann. Carnegie Mus., XI, No.3-4, 1917, p. 440; Fowler, Proc. Acad. Nat. Sci. Philadelphia, LXXXVII, 1935, p. 138; Jones and Silas, Proc. Symposium on Scombroid Fishes, Marine Biological Association of India, 1962, Pt.I, p. 15; Jones and Rosa Jr., Ibid., Pt.III, 1961, p. 1191; Jones and Rosa Jr., FAO Fisheries Synopsis, 1965, No.29.

B. Rastrelliger brachysoma (Bleeker) 1851

Scomber brachysoma Bleeker, Nat. Tijdschr. Ned. Indie, I, 1851, p. 356; Day, Fishes of India, vol.I, reprinted 1958, p. 251.

Scomber neglectus Van Kampen, Bull. Dept. de l'Agric. Indes Neerl. VIII (Zool. ii) 1907, p. 7.

Rastrelliger brachysomus Barnard, Ann. S. African Mus., XXI, Pt.2, 1927, p. 796.

Rastrelliger brachysoma Manacop, Philippine J. Fish., 1956, 4(2), p. 87; Jones and Silas, Proc. Symposium on Scombroid Fishes, Marine Biological Assn. India, Pt.I, 1962, p. 15; Jones and Rosa Jr., Ibid., Pt.III, 1967, p. 1192; Jones and Rosa Jr., FAO Fisheries Synopsis, 1965, 29.

2.2.3 Common names

A. For *R. kanagurta*:

Country	Language	Name
India	English	Indian mackerel
	Canarese	Bangda
	Hindi	Bangdi
	Marathi	Kaulagedar or Bangda
	Malayalam	Ayila or Ayla
	Sindhi	Oibiagedar
	Tamil	Kumla or Kanangeluthi
	Telugu	Kanagurta or Kannangadatha
	Oriya	Karan-kita
Ceylon	Sinhalese	Kumbalava or Maha kara bolla
	Tamil	Ailai, Kumbala or Karungkuluttan
Indo-China	Local language or dialect	Cabacma or Treykanong
Indonesia	Do.	Kembung, Banjar
Malaya Federation	Do.	Kuala muda, Kembong
Japan	Do.	Naha or Gurukun-muchji
Pakistan West	Do.	Surmai
Philippines	Do.	Alumahan, Lumahan, Burau, Salimburaw, Bunatan, Buyaw, Hasa-hasa, Mataan
Singapore	Do.	Kembong
Thailand	Do.	Pla thu
Saudi Arabia and Somalia	Do.	Bagha

B. For *R. brachysoma*:

Country	Language	Name
India	Hindi	Chappata Bangdi
Indo-China	Local language	Cabaoma, Plathu

Indonesia	Local language	Kembung
Malaysia	Do.	Kembong
Philippines	English	Short-bodied or chub mackerel
	Local language	Kabalyas, Aguma-a Kabalyas, Luman, Asa-asa, Hasa-hasa, Linchay, Masangi

2.3 GENERAL VARIABILITY

Morphometric measurements and meristic counts of a large number of specimens of R. kanagurta and R. brachysoma have been examined in detail by Jones and Silas (1964b). The body proportions of 9 characters in the two species showed differences statistically significant at 5% level. In respect of second predorsal distance, length of pectoral fin, anterior height of first dorsal fin and the length of the maxilla the divergence was to the extent of 75% or even more. In the greatest depth of body there has been no overlap, with 100% divergence.

Regarding the frequency of the number of dorsal and anal finlets in the two species the typical arrangement is 5/5 but 6/5 and 6/6 are also met with as exceptions. Jones and Silas (loc. cit.) have observed in R. kanagurta 5/5 in 96.77%, and 6/5 in 3.23%; in R. brachysoma 5/5 in 91.66%, 6/5 in 5.5% and 6/6 in 2.77%. Manacop's (1958) observations show that in R. brachysoma finlet frequency was 5/5 in 92.4%, 5/6 in 5.6%, 6/5 in 0.67%, 6/6 in 0.23%, 5/4 in 0.1% and 4/5 in 0.99%; in R. chrysozonus (= R. kanagurta) 5/5 in 93.50%, 5/6 in 3.90% and 6/6 in 2.60%.

Considerable amount of variation was also met with in gill raker numbers in the upper and lower limits of the outermost right and the left gill arches in both the species examined from Andaman region. There has been a good deal of overlapping. It appears that gill raker count alone is not sufficient to separate the two species. The range of gill rakers observed in R. kanagurta was 17 to 21 (upper limb) + 33 to 42 (lower limb) and in R. brachysoma 17 to 22 (upper limb) + 35 to 42 (lower limb).

The total number of gill rakers on the right arch of the upper and the lower limbs combined has been found to vary from 51 to 61 in

R. kanagurta and 54 to 61 in R. brachysoma. Manacop's (1958) observations on Philippine specimens show the gill raker numbers to be 16 to 24 (upper limb) + 34 to 45 (lower limb) in R. chrysozonus (Syn. R. kanagurta) and 19 to 23 (upper limb) + 34 to 39 (lower limb) in R. brachysoma.

In the specimens from Andamans, variability in a few other characters was also noticed. The length of the longest gill raker in R. kanagurta ranged from 8.2% to 10.4% in fork length and in R. brachysoma from 9.5% to 12.5% in fork length. The length of the longest gill filament in R. kanagurta ranged from 6.3% to 7.5% and in R. brachysoma from 5.3% to 7.5%, but mostly 5.3% to 6.6% in fork length. These results show that the length of the gill raker is relatively longer, but the length of the longest gill filament is relatively shorter in R. kanagurta than the corresponding variables in R. brachysoma.

In regard to racial differences in R. kanagurta no information is available from the published accounts.

Balakrishnan (1969) has examined in detail the dorsal and anal fins of R. kanagurta, obtained from different regions on the Indian coasts and noted the number of rays varying with the size of the fish, the larger fish showing a reduced number of them. He is of the opinion that the dorsal and anal finlets should be regarded as 6 each instead of 5 each, since the last finlet is always double, the two components being close to each other. The increase or decrease in the dorsal or ventral finlet number is accompanied by a corresponding decrease or increase in the dorsal or ventral fin rays. It has also been observed that the endoskeletal supports are constant in number, being 29 in association with the dorsal fin and 18 with the ventral fin.

III. DISTRIBUTION

By

V. Balakrishnan

(Central Marine Fisheries Research Institute, Mandapam Camp)

III. DISTRIBUTION

V. Balakrishnan

3.1 DELIMITATION OF THE TOTAL AREA OF DISTRIBUTION

Rastrelliger kanagurta is widely distributed in the tropical Indo-West Pacific region, roughly from longitudes 30°E to 160°W and latitudes from 30°S to 30°N. It is recorded from almost the entire east coast of Africa, from Malagassy, Mauritius, Reunion Islands, Seychelles, the countries bordering the Red Sea and the Persian Gulf, from the coasts of Pakistan, India, Ceylon, Burma, Thailand, Malaysia, Cambodia, Indonesia, northern Australia, New Guinea, the Micronesian, Melanesian, Polynesian and Solomon Islands, the New Hebrides, Fiji and Samoa Islands, the Philippine Islands, along the coasts of the Peoples' Republic of China and Hong Kong, Taiwan and Ryukyu Islands and some of the central group of Pacific Islands including those of Hawaii(Fig.2).

3.1.1 Distribution in India

In the inshore waters up to about 25 metres the species is well-known to occur all along the east and the west coasts of India viz. from Kathiawar in the north-western coast to Calcutta in the north-eastern coast. It is also recorded from many other places under the Union Territory viz. the Andaman-Nicobar Islands and the Laccadive group of Islands. The trawlers operating from Veraval, Bombay, Karwar, Mangalore, Cochin and Calcutta have obtained the species from the deeper regions of the continental shelf. It often enters the estuaries and backwaters. It has been recorded from the Kali River estuary near Karwar, Netravati estuary near Mangalore and from the Cochin backwaters in Kerala.

Dense shoals of the Indian mackerel appear regularly in certain months of the year along the west coast of India from Ratnagiri (about 17°N lat.) through Malwan, Karwar, Malpe, Tellichery, Calicut, Cochin and Alleppey to Quilon (9°N lat.). More than 90% of the total mackerel catch

of the country comes from the west coast and the fishery is almost exclusively confined to a narrow coastal belt of a width of almost 10 nautical miles.

3.2 DIFFERENTIAL DISTRIBUTION

3.2.1 Areas of occurrence of eggs, larvae and juveniles

Eggs: The earliest reference to the occurrence of the eggs of *Rastrelliger kanagurta* in the plankton collected at Calicut is found in the Administrative Reports of the Madras Presidency, Fisheries Department (1937). Devanesan and John (1940) from Chaliyam near Calicut and Balakrishnan (1957) from Vizhinjam recorded mackerel eggs from the west coast of India. Boonprakob (1963 and 1965) and Matsui (1963) reported their occurrence from the Gulf of Thailand.

Larvae/post-larvae: Kuthalingam (1956) from Madras on the east coast, Balakrishnan (1957) from Vizhinjam on the west coast of India, Matsui (1963) and Boonprakob (1965) from the Gulf of Thailand and Peter (1967 a & b) from the northern Arabian Sea, Red Sea and the Bay of Bengal have recorded the occurrence of the early life-history stages of the mackerel.

Juveniles: Several scientific workers viz. Bhimachar and George (1952), Rao and Basheeruddin (1953), Pradhan (1956), Rao and Rao (1957), George and Annigeri (1960), Basheeruddin and Nayar (1961) and Appanna Sastry (1969) have reported the occurrence of young juveniles from various locations on the east and the west coasts of India. Rao (1964 b) and Jones and Rosa (1965 and 1967) have consolidated available information and presented accounts of the distribution of juveniles of *R. kanagurta* in the inshore waters.

Fig. 2. Geographical distribution of ***Rastrelliger kanagurta***.

IV. BIONOMICS AND LIFE HISTORY

By

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IV. BIONOMICS AND LIFE HISTORY

G. Venkataraman

4.1 REPRODUCTION

4.1.1 Sexuality

Mackerel is heterosexual and two instances of hermaphroditism were recorded one in a specimen caught from Majali, near Karwar (Prabhu & Antony Raja, 1959) and the other in a specimen obtained at Ullal, near Mangalore (Rao, 1962). In the first instance, the left gonad, situated slightly anterior to the right one, showed the characteristics of an ovary and contained yolky eggs ranging in size from 0.15 mm to 0.31 mm mixed with a large number of transparent immature eggs. The right gonad had the characters of a normal testis. The genital ducts (oviduct and vas deferens) emerging from them appear to open outside through a common aperture. The ovary was in stage III of maturity.

In the Ullal specimen the right gonad was an ovo-testis, the testis portion being connected by connective tissue with the ovary portion. The left gonad was a complete ovary. Blood supply to the ovarian and testicular portions of the ovo-testis was common and the ova were in stage III of maturity. As the ovary portion of the ovo-testis was only slightly assymmetrical with the left ovary and as it was directly connected with the oviduct and blood vessels, it is presumed that the testis was an overgrowth on the ovary.

4.1.2 Maturity

Size and age at first maturity: Devanesan & John (1940) stated that mackerel attains maturity at about a length of 190 mm and Chidambaram & Venkataraman (1946) placed it at 200 mm. The minimum size at first maturity as determined by Pradhan (1956) is 224 mm. Radhakrishnan (1965) stated that the mackerel mature for the first time when they measure

210-220 mm in total length. Rao et al. (1965) have indicated that mackerel below 200 mm are immature. From the above observations it can be inferred that the mackerel spawn after the comp[illegible]ion of the second year of their life (Pradhan, 1956 and Sekharan, 19[illegible] or at the end of the first year (George & Banerji, 1968). It is po[illegible]le to distinguish sex in fish of about 120 mm in length.

4.1.3 Spawning

Spawning season: Earlier workers who examined the maturity stages of mackerel from Calicut coast observed that spawning season of mackerel extends from June to September (Devanesan & John, 1940 and Devanesan and Chidambaram, 1948). Chidambaram and Venkataraman (1946) advanced the commencement of the spawning season by one month, i.e. from June to May. Chidambaram et al. (1952) noted the ripening of gonads in March-April and May and placed the spawning season from April to September. The observations of Bhimachar & George (1952) agreed w[illegible]h the above finding. Panikkar (1952) stated that the spawning period on the west coast corresponds with south west monsoon. According to Pradhan (op. cit.) the spawning season of mackerel at Karwar extends from June to September. Subsequently, Radhakrishnan (1965) recorded mature and spent mackerels, also in November at this place. Sekharan (op. cit.) examining specimens caught off South Kanara coast reported that the spaw[illegible]g starts in April itself, if not in March. Further north at Ratnagiri, there were indications of two spawnings, one in early May and another at the end of September or the beginning of October. The studies carried out at Mangalore showed that spawning takes place from March to October (Rao et al. (op. cit). The s[illegible]e authors indicated the possibility of mackerels spawning throughout [illegible] year with peaks at certain intervals. George, et al. (1959) mentioned the probability of a longer or a su[illegible]sidiary spawning season along the Mangalore coast. The occurrence [illegible] individuals in maturity stages of V and VI b in Cannanore as late as October and of partially spent or fully spent specimens at Calicut in the same month show[illegible] th[illegible] [illegible] spawning season extends up to October along the Malabar coast (Q[illegible]. Sci. Repts. of CMFRI for Dec. 1961 and for Dec. 1965). It is int[illegible]resting [illegible] note that in 1966 mackerel in [illegible]vanced stages of V and VI were not[illegible] at Calicut in March itself, ahead of the usual

spawning period i.e. April-May (CMFRI Annual Rept., 1966). Rao (1964b), analysing the maturity stages and also distribution of young stages of mackerel as recorded by different workers, felt that on the west coast intensive spawning takes place during July-August followed by a supplementary spawning in November-December. He also observed that intermittent spawning in between the two periods is likely and the spawning may be a prolonged one extending from March to December. At Cochin, spawning seems to be from April to July as evidenced by the occurrence of advanced stages of IV to V (CMFRI Annual Repts., 1961, 1964, 1965).

On the south west coast of India, off Vizhinjam, investigations have led to the inference that mackerel spawn from about October till the end of February (Rao, 1965) and from earlier studies at the same centre it was indicated that the fish spawned during 1955 and 1956 from early March to July (Balakrishnan, 1957). Bennet (1967), based on the occurrence of juveniles, has mentioned the possibility of two main spawning seasons for mackerel at Vizhinjam one from March to May and another from August to September with a subsequent minor spawning season from December to January. He even envisages the possibility of the existence of two spawning stocks drawn from west and east coasts of India. Observations made at Mandapam on the south east coast of India also indicated the possibility of two spawning periods, one during October-November and the other major spawning in May-June (CMFRI Annual Rept., 1957). Subsequent studies made at Mandapam showed that the maturation process starts much earlier by about second half of January itself and by March stages III, IV and V predominate. Some ripe specimens (Stage VI) have also been recorded during this period. In April to November months in addition to fishes in above stages, spent and spent-recovering specimens have been found in the collections (CMFRI Annual Rept., 1967). At Porto Novo, the gonadial studies showed that the first spawning takes place in April or May (CMFRI Annual Rept., 1959).

In contrast to this, the occurrence of young mackerel off Madras in March-April months of 1953, 1954 and 1955 (Rao and Basheeruddin, 1953 and Basheeruddin and Nayar, 1961) indicated that the fish breed during or after the north east monsoon on the east coast. Investigations made on the maturity condition of mackerel caught in Lawson's Bay, off Waltair, showed that the spawning season commences by about October or November and lasts until April or May coinciding with the north east monsoon (Rao, 1964a). Sastry

(1969) recorded juveniles of Indian mackerel of size range 46 to 168 mm for the first time from Kakinada area on the east coast during March-May period. Rao (1964b) inferred that the intensive spawning period for this species on the east coast is from about October to December, with a second spawning period being likely in about April. In Port Blair (Andamans) the peak spawning season seems to be from November to January (CMFRI Annual Rept., 1964).

It could be seen that both on the west coast and east coast of India the spawning season is a prolonged one, extending from about March to October on the west coast and from about October to April on the east coast, with some variations in some areas. A supplementary spawning in November-December is indicated in some places on the west coast. In both the coasts, the intensive spawning season seems to coincide with the monsoon periods.

Spawning frequency: Pradhan (1956) observed that the Indian mackerel spawns in succession and only a small percentage of ova mature each time. Ova diameter studies carried out at Malpe (Sekharan, 1958) showed two peaks, one for the immature group and another for maturing group. Within the maturing group, eggs, both opaque and those in various stages of transparency were in different modal stages, thereby indicating that the eggs are ripened and released in batches. The author does not rule out the possibility of the other eggs undergoing degeneration, after the first batch is shed.

Subsequent investigations (Radhakrishnan, 1965) made at Karwar and Porto Novo (Vijayaraghavan, 1965) confirmed the observations of Sekharan (op. cit.) though some difference was noted in certain details by the latter author. In Karwar specimens, several minor modes were observed within the mature group of ova (measuring about 0.323 to 0.612 mm) and there was also a group of ripe ova (0.629 to 0.749 mm). Since there was a well marked differentiation in the modes of the mature group, it is obvious that the eggs in this group would ripen in batches, as and when ripe ova would be shed. It has also been noted that the duration of shedding of ova extends over a long period (Fig.3,4 and 5). Vijayaraghavan (op. cit.) examining the mature group of ova under greater magnification found the existence of a series of distinct modes which made clear that the ripening group of ova would reach the final stages of maturity in well defined batches. He did not agree with the possibility that after the first batch of eggs is shed the others may undergo degeneration (as

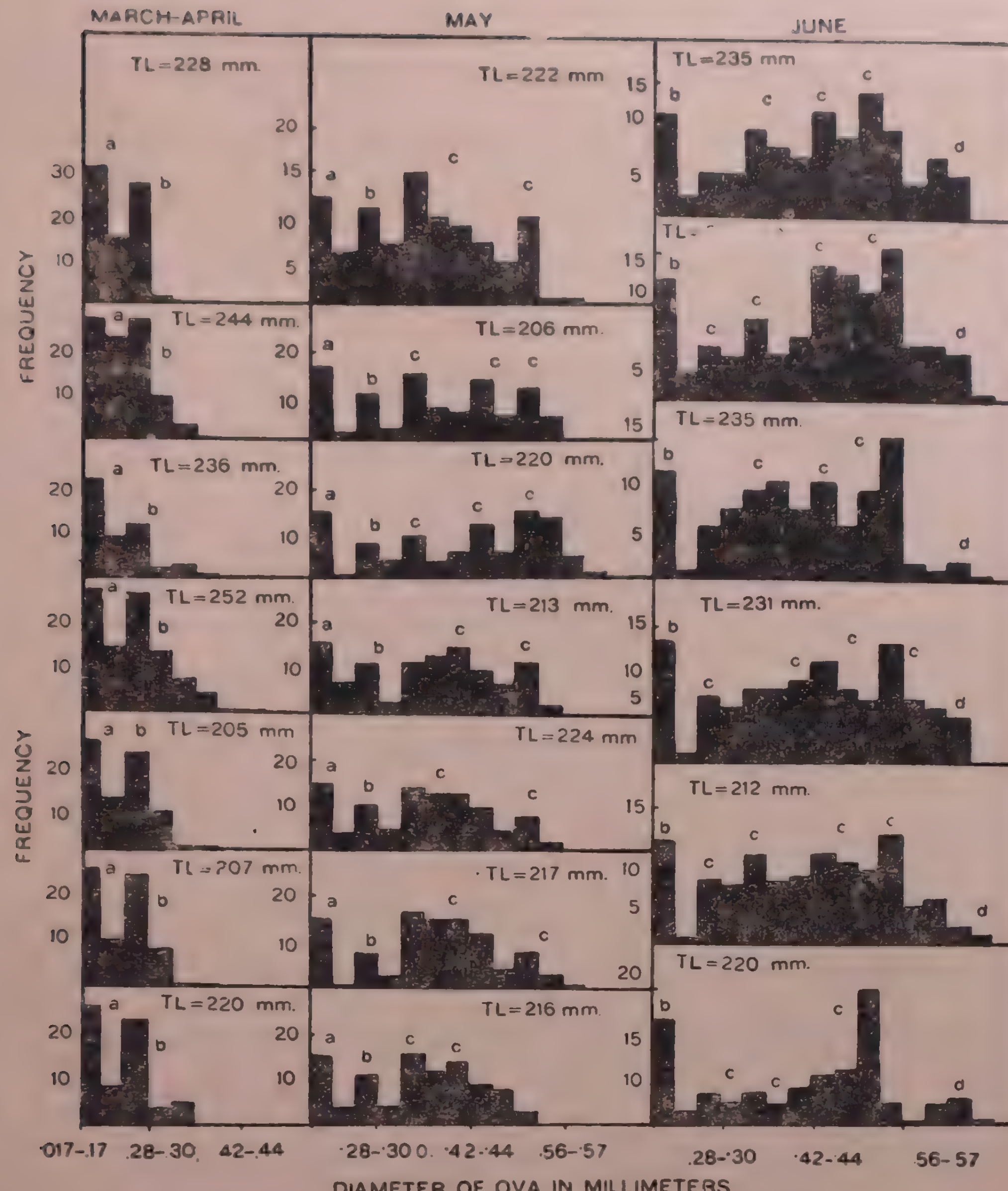

Fig. 3. Ova diameter frequency of ***Rastrelliger kanagurta*** during March-June at Karwar (Reproduced from Radhakrishnan, 1965).

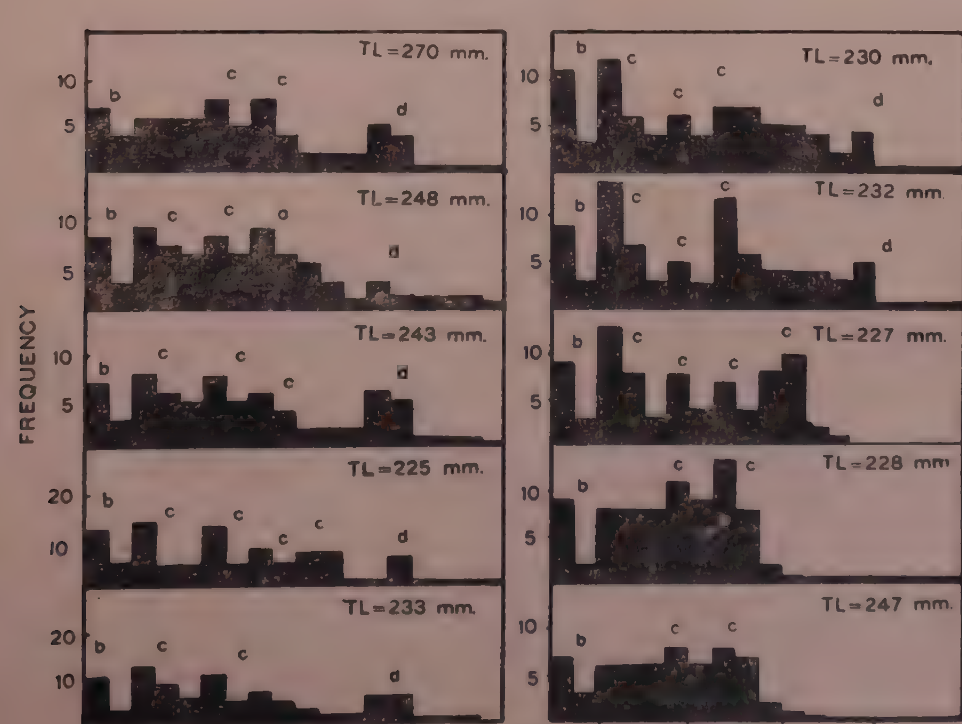

Fig. 4. Ova diameter frequency of ***Rastrelliger kanagurta*** during July at Karwar (Reproduced from Radhakrishnan, 1965).

expressed by Sekharan, 1958). His conclusions were supported by the samples of fish obtained, representing almost a continuous gradation of ovaries ranging from fully ripe but unspawned to fully spent condition. Rao (1964a) concurred with the view expressed by the previous workers that the mackerel releases eggs in batches since he found that in the final stages of maturity the ova diameter frequency curves exhibit multiple modes. He also noted that mature ova are seggregated in two distinct groups in the final stages of maturity thereby suggesting that individual fish may spawn probably twice in the spawning season. He further observed that as the proportion of the remaining mature ova, after the release of the first batch was very high, it was felt very unlikely that all of them would be reabsorbed, although some reabsorption of residual ova was observed.

Spawning time: Devanesan & John (1940) have stated that spawning takes place at nights. Vijayaraghavan (1963) examined over 3000 fish caught at Porto Novo in each season for a period of four years, but did not observe even a single fish with running ovary in the day catches. He got a few specimens with ova oozing out, only from the night catches, indicating the possibility of spawning being confined to night.

Spawning ground: Devanesan & John (op. cit.) were of the opinion that mackerel recede from coastal waters during the south west monsoon period for the purpose of spawning. From the occasional occurrence of spent ones in the inshore catches they believed that the fish after spawning do not permanently retire to deep sea, but come back to coastal waters and that their spawning grounds are not very far from the coast. They mentioned Chaliyam, a place 5 miles off Calicut as a breeding place for mackerel as they collected what they believed to be mackerel eggs. The region between Vizhinjam and Cape Comorin off the south west coast of India appears to be a spawning ground, as spawners, young mackerel and post-larvae have been obtained in this region. But the spawning seems to take place outside the present fishing limits beyond 3 miles from the shore (Balakrishnan, 1957).

Table I

Key to the stages of sexual maturity of the female Indian mackerel (Rastrelliger kanagurta)

Extent of ovary in the body cavity	Range of ova (mm)	State of maturity	Maturity stage
Ovary less than half the length of the body cavity	0.038-0.13 0.14- 0.27	Immature	I
Ovary slightly more than half the length of the body cavity	0.28 -0.37	Maturing	II
Ovary extending to about 2/3 the length of the body cavity	0.37 -0.46	Maturing	III
Ovary extending a little over 2/3 the length of the body cavity	0.46 -0.56	Maturing	IV
Ovary extending over the entire length of body cavity	0.57 -0.81	Mature	V
Ovary extending over the entire length of body cavity	0.57 -0.81 0.57 -0.81	Mature Mature	VI(a) VI(b)
Shrunken ovary about 1/2 the length of abdominal cavity	..	Spent	VII

(After Jones and Rosa, 1965)

Table II

Key to the stages of sexual maturity of the male Indian mackerel (Rastrelliger kanagurta)

Extent of testes in the body cavity	State of maturity	Maturity stage
Testes less than half the length of the body cavity	Immature	I
Testes slightly more than half the length of the body cavity	Maturing	II
Testes extending to about 2/3 the length of the body cavity	Maturing	III
Testes more than 2/3 the length of the body cavity	Maturing	IV
Testes extending over the entire length of the body cavity	Mature	V
Testes extending over the entire length of the body cavity	Mature	VI
Testes comparatively much reduced in size	Spent	VII

(After Jones and Rosa, 1965)

Plate I a. Ovary of mackerel in stages V-VI.

Plate I b. Magnified view of the portion between the dotted lines in Plate I a.

4.1.4 Fecundity

The only record of the fecundity estimation in mackerel is by Devanesan & John (1940) who have estimated an average of 94,000 eggs in mackerel.

The maturity key as recommended by the International Council for the Exploration of the Sea in the Herring (Wood, 1930) is followed by the workers of C.M.F.R.I. with modifications as given by Pradhan and Palekar (1956) who subdivided stage VI into stage VI (a) and VI (b) which are described as plum-pudding stage, the ovary having a speckled appearance due to the peculiar mode of the ripening of ova in batches (Plate I a & b). The keys prepared by them for male and female mackerel are given in Tables I and II respectively.

4.1.5 Egg structure

The diameter of the plankton eggs collected by Devanesan and John (op. cit.) varied from 0.54 mm to 0.70 mm. They thought these eggs belonged to that of Indian mackerel as they occurred in a place where ripe mackerel shoaled and the planktonic eggs closely resembled in size and character those obtained from a spawning mackerel. However they agreed that conclusive proof can be had only when spawning fish are obtained and artificial fertilization is carried out.

The range of ova diameters in different stages described by Pradhan and Palekar (op.cit.) is as follows: 0.038 to 0.27 immature, 0.28 to 0.56 maturing, 0.57 to 0.81 mature. The highly advanced ova are transparent measuring 0.88 to 0.90 mm usually with a large oil globule whose diameter is 0.23 mm. Balakrishnan (1957) found the ova from mature fish measuring 0.6 mm to 0.84 mm and the planktonic eggs, tentatively assigned to mackerel, measuring from 0.84 to 1.009 mm. Vijayaraghavan (1965) studying modal distribution of ova in twenty fishes found them showing three prominent modes - "the immature ova measuring less than 0.160 mm, another around 0.288 mm which were maturing and a third around 0.672 mm representing the mature ones..." Radhakrishnan (1965) classified the ova into four categories, immature, maturing, mature and ripe the respective diameter ranges being 0.017 to 0.170 mm, 0.255 to 0.272 mm, 0.323 to 0.612 mm and 0.629 to 0.749 mm. The maximum size of the intraovarian egg recorded by him is 0.935 mm; the fully transparent ovum has a single large oil globule measuring 0.20 to 0.25 mm.

4.2 AGE AND GROWTH

4.2.1 Age

Only in the recent past, efforts have been made to determine the age of mackerel based on length frequency analyses (Pradhan, 1956; Sekharan, 1958; Balakrishnan, 1962 and George and Banerji, 1968). An attempt has been made to interpret the significance of rings observed in mackerel scales (Seshappa, 1958).

Pradhan (op. cit.) after analysing length frequency data of mackerel from Karwar during the years 1948-49 to 1952-53 came to certain conclusions on the age of mackerel. The pattern of occurrence of different size groups in different months is as follows. In July-September period juveniles of size range 6 to 11 cm are occasionally caught. In the first half of September, a slightly larger group of 12 to 16 cm occurs in the fishery. This group is succeeded in October by a still larger size group of 18 to 20 cm which usually constitutes the mainstay of commercial fishery. Higher size groups of 21 to 22 cm are met with during February to March. Mackerel in the maximum size range of 22 to 25 cm are caught during the spawning season i.e. from June to September. The cycle is repeated from the commencement of the next mackerel season.

Pradhan (op. cit.) believes that the juvenile mackerel of size 6 to 11 cm encountered in July-September period presumably are the offspring of fish which have spawned in the previous fishing season. The average length of this fish which is a year old is about 10 cm. These juveniles do not contribute to the fishery in the succeeding months but leave the inshore waters. This fish grows to about 14 to 16 cm by about April and it enters the fishery in the following season when it reaches a length of 18 cm or more. At the time it enters the fishery it is about two year old. The 12 to 16 cm size group commonly observed in the first half of September is presumably more than one year old and it attains a size of about 22 cm or above in the next spawning season when it matures and spawns. From the above observations, it is deduced that the rate of growth of Indian mackerel is slow and it attains a length of 10 cm in one year and at the time of its entry into the fishery in October it completes its second year, the length being 18 cm or more.

Sekharan (1958) analysed the length data on mackerel collected by him at Malpe for two seasons 1954-55 and 1955-56 and also examined the data on length frequency of mackerel for the period from 1934-35 to 1940-41 from the West Hill area published by the Madras Fisheries Department. The data at Malpe showed that the fishery drew its support mainly from single age group consisting of 180 mm; 190 mm and 210 mm groups. From the analysis of West Hill data, Sekharan (op. cit.) inferred the rate of growth and average sizes of mackerel at different ages by tracing the progression of monthly modes. The data showed that usually in the month of July juveniles having a modal range of 12 to 14 cm occurred in the fishery. In August-October period they also fluctuated between 16 and 20 cm. In some years, 19 cm group was seen in the fishery during the same period and in August 1940, there was a modal group at 17 cm. Sekharan (op. cit.) considered that all these groups, when they form the mainstay of the catches, belong to roughly the same age class (in the second year of their life). He considers the juveniles of size 12 to 15 cm occurring in July as having completed just one year of their life. He traced these one year old groups through one fishing season till next May-July period by which time they attained a size of 21-23 cm and completed the second year. Thus, according to this author (op. cit.) mackerel reaches a size of 12 to 15 cm at the end of the first year of its life and 21 to 23 cm at the end of the second year of its life. He is unable to arrive at the total life span of the fish, as mackerel measuring above 25 cm are scarce in the commercial catches.

Seshappa (1958 and 1970) observed growth rings in the scales of mackerel measuring over 22 cm, and inferred that the rings are likely to be spawning marks. The first ring is found in specimens measuring over 22 cm at which size the first spawning also takes place. In 25-27 cm group, two growth rings are noticed and in still larger specimens indications up to 4 rings are seen. Analysing all the data together, Seshappa (op. cit.) considers that the west coast mackerel attains a length of 12 to 16 cm at the end of the first year of its life and 21-24 cm at the end of the second year. The length reached by the end of the third and fourth year of life is about 25-27 cm and 28-29 cm respectively. At the end of five years, it is around 30 cm in length.

Balakrishnan (1962) - as quoted by George and Banerji (1968) - based on his studies of mackerel at Vizhinjam during 1955-57, is of the view that the fish measuring 14 cm may be one year old and those in the size groups of 19 to 21 cm may have completed 2 years of life. The specimens (23 cm and above) would have completed 3 years and they may comprise more than one age group.

George and Banerji (op. cit.) made a study of the length frequency data on mackerel collected at Cochin for 7 seasons from 1957-58 to 1963-64 and also reanalysed the length data published by Pradhan (1956) and Sekharan (1958). They, after finding out the modes in different months for all the seven seasons, calculated the average size of mackerel in successive months from the time of their first appearance in the fishery and traced the same from month to month relating it to its age. Starting from a size of 9.5 cm when it is two months old, the fish grows to a size of 21.6 cm at the end of 12 months. Thereafter the growth slows down considerably. Similar analysis of modes at Karwar and Calicut and the pooled average size data at different ages for all the three places, showed similar growth pattern. A growth estimation made by applying Bertalanffy equation showed satisfactory agreement with observed values. Estimation of age of older fish becomes difficult, due to drastic retardation in growth and consequent overlap of size and age class occurring in them.

The conclusions of George and Banerji (op. cit.) may be briefly summarised as follows. The Indian mackerel according to them attains a size of about 22 cm at the end of the first year of its life and probably 24 cm at the end of the second year. The commercial fishery mainly comprises of sizes 18 to 22 cm which are in the 0 year or just completing the first year of its life. The success of the fishery depends upon the strength of a single year class i.e. 0 year class which is subject to considerable fluctuations from year to year. The strength of the 0 year class in turn depends upon the survival rate of the young and the environmental factors influencing its immigration into the fishing zones.

4.2.2 Rate of growth

Pradhan (1956) observed a progressive growth in the length of mackerel from the fishing season (October to March) to the spawning season (June to September). The monthly average length during the season fluctuates

by 2 or 3 cm which shows the growth in length during the season. An increase of 1 to 2 cm is noted in the succeeding months to August. Sekharan (1958) also noted well-marked periodicity in the rate of growth of the year classes in the commercial age group. He found that the growth is most rapid during July-September period (3-7 cm) after which it declines in October-December (2-3 cm), the minimum being in January-June (1 cm). From an analysis of the length frequency data on mackerel collected from Lawson's Bay, Waltair, Rao (1964a) deduced that the juvenile mackerel grows very rapidly, probably at the rate of 2 to 3 cm per month and the lengths 5-6 cm and 15-16 cm most likely represent about 2 months' and 7 to 8 months' growth respectively. Balakrishnan (1962) observed that mackerels grow fast at the rate of more than 1 cm a month during the first year. Radhakrishnan (1967) estimates that the "monthly growth rate of a brood immediately after it enters the fishery is about 20 mm or more".

4.2.3 <u>Age groups and broods</u>

Investigations carried out on the mackerel fishery of the Mandapam area showed (Sekharan, 1965) that the fishery appears to be supported by a single age-group whose modal size varied from 227 to 242 mm during the December-March periods of 1952-56. These modal sizes are larger than those occurring at Malpe and Karwar during the December-March period. At Mangalore the catches appear to be supported by fish in the second year of their life (Rao <u>et al</u>., 1965). Radhakrishnan (<u>op</u>. <u>cit</u>.) based on the length frequency analysis of mackerel caught off Karwar opines that mackerel of size 115 to 155 mm, encountered in the fishery, "are obviously the products of the current years spawning" and believes "that the fishery of Indian mackerel is largely dependent on 0 and 1 year class individuals". At Vizhinjam, 0 to 2 year groups occurred in the commercial catches during 1960-63, the minimum and maximum size being 3.5 cm and 28.0 cm. Of these, the 0 year group dominated in the landings (Bennet, 1967).

Length frequency studies carried out at Mangalore (Rao <u>et al</u>., <u>op</u>. <u>cit</u>.) suggested the possibility of more than one brood in a year occurring in the fishery, although all broods may not be equally successful or contribute to the catches of a particular area.

Rao (1964b) studied the distribution of the young stages of mackerel and by tracing back the modal values of mackerel population in different months from the very older groups to the younger ones on record,

indicated that on the west coast of India two distinct groups of young ones, being the offsprings of spawners that spawned in July-August and November-December respectively, enter the inshore waters in different periods of a year.

It could be seen that there is no agreement among the workers as regards the age of the fish. They have drawn their conclusions based on length frequency analyses. There are missing links in the progression of modes, specially in earlier stages which some workers have tried to fill up on a hypothetical basis based on the rate of growth observed in the previous years for the same periods. The tracing of the progression of modes, from month to month, is rendered difficult especially in earlier stages due to the prolonged spawning season and consequent recruitment of different broods in the fishery. Corroborative evidence in the form of growth checks in otoliths, scales etc. which can be related to age is lacking. The recoveries from the tagging experiments have been very few and do not give any indication of the age and growth of the fish. Direct evidence based on growth checks on scales and in the hard parts, tag recoveries and laboratory experiments on the growth rates of larval, post-larval and juvenile fish is required before a consensus on the age of the fish can be arrived.

4.2.4 Longevity

Pradhan (1956) believes that at the time the fish enters the fishery in October (about 18 cm in size), it has completed its second year of life. Sekharan (1958) envisages the possibility of other age groups besides the one and two year olds in the population though he is unable to arrive at the total life-span of the fish. Rao *et al.* (1965) state the effective life-span of mackerel is about 4.91 years. The calculated age lengths at age I, II, III and IV years are 150.7, 225.3, 266.2 and 288.9 mm respectively. George and Banerji (1968) say that this fish attains 216 mm at the end of the first year of its life and 240 mm at the end of second year, beyond which they are not in a position to determine the age of the fish. Seshappa (1970) estimates that the life span of this species may well be over 6 to 7 years.

4.2.5 Greatest size

The largest size recorded from Vizhinjam was 320 mm. (Rao, 1965).

4.3 FEEDING

A number of contributions on the food of mackerel has appeared and it has been possible to get a broad idea of its food and feeding pattern both on the east and west coasts of India. Studies made on the west coast have shown it to be mainly a plankton feeder feeding both on phyto- and zooplanktonic organisms, comprising mainly of diatoms, dinoflagellates, copepods, cladocerans, larval and adult decapods. Some of the other food elements met with in the stomach contents were gastropod and bivalve larvae, polychaete larvae, cirripede nauplii, appendicularians, cypris larvae, mysids and fish eggs and larvae (Bhimachar & George, 1952; Pradhan, 1956; Venkataraman, 1961; Noble, 1965). Observations made on the east coast also showed it to be a plankton feeder, feeding both on phyto- and zooplanktonic elements (Chacko, 1949; Rao, 1964a). The variations in the occurrence of different planktonic elements from season to season, were correspondingly noticed in the stomach contents also. However, there is disagreement among the workers regarding the quantitative occurrence of various planktonic organisms in the stomach contents. While Bhimachar and George (op. cit.) noted that the planktonic forms occurred in the stomachs of mackerel of Calicut coast in proportion to their availability in the plankton, it was observed at Karwar "that the order of abundance of various planktonic organisms is not always the same in corresponding analyses" of plankton (Pradhan, op. cit.). But subsequent investigations carried out at the same centre showed that the "quantity and quality of the food of mackerel vary with the variations in planktonic elements in the inshore area" (Noble, op. cit.).

An examination of the stomachs of mackerel obtained by drift nets in the relatively deeper waters (33-46 m) off Vizhingam in south Kerala (Rao, 1965) revealed the presence of pelagic tunicates, *Pegea confoederata*, *Ritteriella amboinensis* and *Thalia democratica* which abound in the open sea from where the fish were caught (Fig. 5). They have rarely been seen as part of the food of mackerel from inshore area and their presence, in the stomachs, shows that "the food consumed by the fish living in different waters vary to a certain degree depending upon the exigencies of the environment" as was observed in the European mackerel, *Scomber scombrus* (Allen, 1897; Bullen, 1908 and Steven, 1949).

Although mackerel feeds on a large variety of organisms, a certain amount of selectivity in feeding has been noticed. The dinoflagellate, Noctiluca is almost totally avoided by this fish, even though it may be present in the plankton in abundant numbers. Bhimachar and George (1952) differentiated the plankton of the Calicut coast into edible and non-edible parts, and the latter part comprising of arrow worm Sagitta, salps, medusae, ctenophores, spionid and stomatopod larvae, though common in plankton, was scarce in the stomach contents. These observations were confirmed by workers in other centres also (Pradhan, 1956; Rao and Rao, 1957 and Noble, 1965). Mackerel is primarily a filter feeder. However the presence of macro planktonic organisms like Lucifer, mysids, Acetes etc. suggests that larger organisms are taken in by visual selection (Kutty, 1965). Such visual feeding has been observed in Scomber scombrus also (Bullen, 1912; Steven, 1949).

There is a large measure of agreement among the workers on the food of the adults. But, different views have been expressed on the variations between the food of juveniles and adults. Bhimachar and George (op. cit.) and Pradhan (op. cit.) have observed no appreciable difference between the food constituents of the young and the adult. George and Annigeri (1960) after examining a large sample of mackerel below 100 mm from Ratnagiri coast have found that the food of the young mackerel comprised of the same items as seen in adults and believed that the feeding pattern of the young mackerel was not different from that of adults. A reexamination of young mackerel collected from the Madras coast by Rao and Basheeruddin (1953) lead George (1964) to the same conclusion. Sastry (1969) observed the juvenile mackerel at Kakinada to be predominantly a plankton feeder as noticed in the adults.

However, different findings have been recorded by other workers. The food of the juveniles of size 3.2 to 8.9 cm obtained from Waltair on the east coast was found to consist "mostly of fish larvae and Lucifer sp. indicating their preference to this diet". But in contrast, the food of the adults (9 cm and above) comprised of mostly copepods, diatoms, dinophysids and larval decapods and stomatopods, there being no trace of fish in the stomach contents (Rao and Rao, 1957 Rao, 1964 a). Chidambaram (1944) and Devanesan and Chidambaram (1948) recorded white baits in the

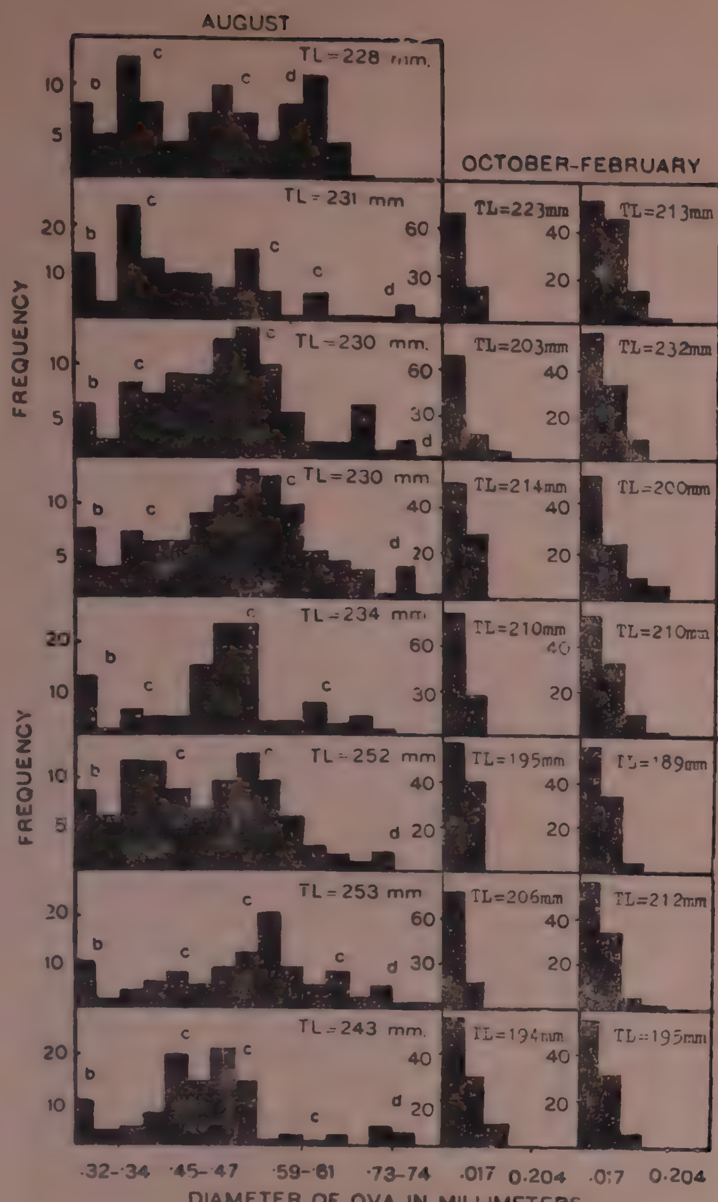

Fig. 5. Ova diameter frequency of ***Rastrelliger kanagurta*** during August and October-February months at Karwar (Reproduced from Radhakrishnan, 1965).

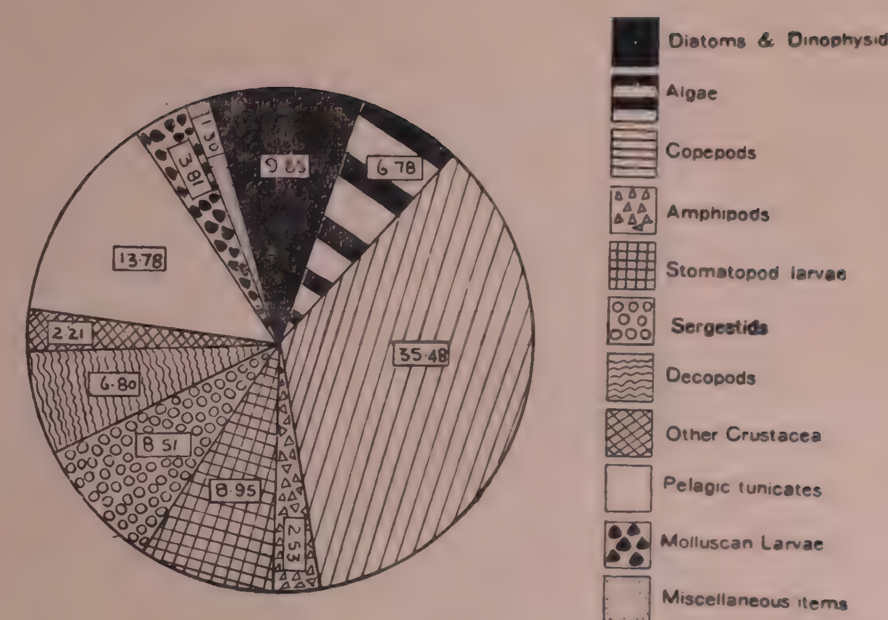

Fig. 6. Food composition of mackerel, ***Rastrelliger kanagurta*** at Vizhingam in volumetric percentage (Reproduced from Rao, 1965).

stomachs of young mackerel obtained from Calicut and mention that this indicated a carnivorous habit of young fish. The stomachs of 75 specimens of young mackerel of length 6.4 to 11.3 cm caught off Vellayil, near Calicut in June 1966, were found gorged with parts of fish (clupeids) and fish scales (Venkataraman and Mukundan, 1970).

Kuthalingam (1956) based on his investigations on the food of mackerel from Madras coast categorised the nature of feeding in relation to size of the fish. He found the post-larval forms to be herbivorous feeding on diatoms and other algae and juveniles omnivorous feeding on all surface forms available in the area. According to him, the adults are carnivorous, as post larval and juvenile teleostean fish were found in the stomachs. But the size of the specimens he has included in the adult category starts from as low as 3.5 cm in length. Noble (1965) found the adults at Karwar to be exclusively plankton feeders as "fish larvae and vertebrate materials were totally absent in the guts". Rao (1965) in his analysis of stomach contents of adult mackerels of size 24 to 32 cm from Vizhinjam area did not come across any fish or parts of fish and doubts the piscivorous habits of the adult fish as mentioned by some workers since "they are likely to have been taken fortuitously; a habit often observed in mackerel when they are enclosed in the boat seines and shore seines".

In the course of the examination of the food of young mackerel, an interesting feature observed at Waltair is "the higher proportion of phytoplankton in the diet of larger fish than in the younger ones" (Rao and Rao, 1957; Rao, 1964a). Further Rao and Rao (op. cit.) have found the relative length of the digestive tract to be greater in the adult fish than in the juveniles and this they correlated with the differences in the food habits of the juveniles and adult fish.

The presence of sand grains and fish scales in the stomach contents, recorded by some workers suggests that mackerel, though essentially a plankton feeder, at times resorts to bottom feeding (Chidambaram, 1944; Devanesan and Chidambaram, 1948; Bhimachar and George, 1952; Pradhan, 1956; Noble, 1965 and Kutty, 1965). Devanesan and Chidambaram (op. cit.) mention that the mackerel "supplements its diet of planktonic organisms by

occasionally feeding at the bottom on dead and decaying fishes, for, in the stomach at times fish scales and sand grains without any traces of fish bones are found". Noble (1965), who agrees with the opinion expressed by Pradhan (1956), states that the inclusion of sand grains in the stomachs might be due to particular mode of fishing and that the scales could have accidentally gone into the stomachs during their brushing up with one another inside the rampan nets. That mackerel, at times, feeds at bottom is proved by the "presence of sand grains, foraminiferans, fish scales and molluscan shell bits" in the stomachs of mackerel obtained in the trawl catches of the Bombay coast (Kutty, 1965). The possibility of subsurface feeding also has been indicated by Bhimachar and George (1952) who have found that when surface plankton is composed of non-edible elements "the food of the mackerel, as seen from examination of the stomach contents, matched more with the bottom than the surface plankton".

Though the food of mackerel as worked out in different centres of the east and west coasts agree in a broad measure, some local differences in the matter of detail have been noted. Devanesan (1942), Chidambaram (1944) and Devanesan and Chidambaram (1948) found fish eggs as a regular item of food in the stomachs of mackerel from Calicut coast and they have stated that this habit would have an adverse effect on the population of the fishes on whose eggs it feeds. But John and Menon (1942) examining specimens from Trivandrum coast did not find any fish eggs in the gut contents. However, subsequent investigations carried out at Calicut, Karwar and Vizhinjam confirmed the presence of fish eggs in the stomachs, though only occasionally (Bhimachar and George, op. cit.; Pradhan, op.cit.; Noble, op. cit. and Rao, 1965). Another food item on which the findings of the workers differ is the alga, Trichodesmium. Whereas John and Menon (op. cit.) did not find this alga in the food of mackerel and oil sardine of Trivandrum coast, Chidambaram (op. cit.) observed the same in good quantities in the stomachs of mackerel caught from Calicut area. But this was not noted in the stomach contents of mackerel during later investigations carried out at Calicut and Karwar (Bhimachar and George, op. cit. and Noble, op. cit.). Large quantities of brown and red algae have been recorded in the stomachs of mackerel obtained from 18-25 F area off Vizhinjam. However, their occurrence in the stomachs is considered exceptional as mackerel do not normally eat them (Rao, op. cit.).

It has been found that the feeding intensity in mackerel is low during the prespawning and spawning periods, while in maturing specimens, it is high (Bhimachar and George, 1952; Chidambaram et al. 1952 and Noble, 1965). It has also been noted that in spent condition feeding is comparatively more than in mature specimens and in the mackerels of size range 18.5 to 25.0 cm there was an alteration of high and low feeding intensity in successive size groups except in 24.0 cm size group (Noble op. cit.). Chidambaram et al. (op. cit.) have observed two periods of intense feeding in mackerel of Calicut coast (noted by Bhimachar and George also), one in October-December and the other in March-April. A corresponding increase in the fat content has also been seen during the respective periods. Similar maxima in the feeding intensity were noticed at Karwar also (Noble, op. cit.).

To sum up, it is seen there is agreement among the workers that mackerel is pr marily a plankton feeder, feeding both on phyto and zooplanktonic elements. Most of the workers have noticed selectivity in feeding, as evidenced by the avoidance of certain elements in the plankton and by the presence of macroplanktonic organisms in the stomach contents. The oc urrence of sand grains and fish scales in the stomachs have been noticed by a majority of workers, but opinion is divided as to whether they are accidental inclusions in the stomachs or whether mackerel resorts to bottom feeding at times. In this context it is significant to note that sand grains, foraminiferans, molluscan shell etc. were recorded in the stomachs of mackerel caught in the trawl catches of the Bombay coast (Kutty, 1965). The occurrence of fish eggs in the stomachs of mackerel has been observed by most of the workers, but it is doubtful whether this habit would have any adverse effect on the population of the fishes on whose eggs it feeds (a view put forwarded by some workers) as these eggs are taken in stray numbers and that too occasionally. On the question of differences in the food of juveniles and adults, the findings are at variance, but the fact that in many instances fish and parts of it have been noted in the stomachs of juveniles show that they take to fish diet if available in the environment. That to some extent mackerel modifies its diet according to its availability in the environment is seen from the occurrence of pelagic tunicates in the

stomach of mackerel caught off Vizhinjam coast (Rao, 1965). Observations made at Calicut and Karwar showed that there is a slackening in feeding during spawning and prespawning periods, the feeding being high in maturing specimens. Two periods of intense feeding have been noticed at both places with a corresponding increase in the fat content.

Fairly detailed knowledge on the food of mackerel from inshore area is now available, but it is restricted to certain centres and related to certain periods of time. Further no quantitative estimation of plankton has been made so as to correlate it with the food of mackerel except at Calicut and Karwar. A simultaneous study on the qualitative and quantitative aspects of the food of mackerel and the plankton available in its environment from all centres of study on the west and east coasts have to be made over a period of time which will give an integrated picture of the food of mackerel and will in all probability throw some light on coastal migrations and fluctuations in the fisheries.

While Bhimachar and George (1952) have stated that the shoreward migration of mackerel shoals during post monsoon season is for purposes of feeding, other workers (Pradhan, 1956 and Sekharan, 1958) do not subscribe to this view. At present we have no idea of the food of mackerel in offshore waters, except for brief observations by Kutty (1965) and Rao (1965) on the food of mackerel from relatively greater depths. It is very essential to make studies on the food of mackerel from offshore areas and on the food in its environment before we can form an opinion on this question.

In order to facilitate comparison of the results obtained, it is necessary that same methods are followed in the estimation of the food contents and plankton in all the centres of observation. There is considerable confusion in the usage of words 'juvenile' and 'adult'. Whereas in one instance mackerel measuring 9 cm and above has been treated as an adult, in another instance the range in the length of an adult is from 3.5 to 22.5 cm. Terms denoting the food habits have been loosely used, thereby creating considerable difficulties in the understanding of the same. Such confusion can be avoided by standardising the definitions and by following uniform methods of analysis.

4.4 BEHAVIOUR

4.4.1 Migration

The large scale occurrence of juvenile mackerel in the inshore region during the period immediately following the monsoon is suggestive of migration of this fish from offshore to inshore waters. The inference drawn by Bhimachar and George (1952) that food could form a major factor governing these migrations is contended by Pradhan (1956) and Sekharan (1958). Pradhan (op. cit.) felt that without studying the plankton available in the offshore waters the shoreward migration should not be linked with the food factor. Sekharan (op. cit.) observed that "the 0-year-class is practically absent from the landings at a time when plankton of the coastal waters is richest in edible forms" and hence stated the question of food playing a dominant role in offshore to inshore migrations needs to be verified. The evidence provided by different workers that the spawning ground may not be far off from the usual fishing belt (30 m depth) indicate that the migration of spawners to coastal waters is probably induced by the special ecological conditions caused by the monsoons.

The fact that the mackerel fishery does not start and close at the same time in different areas of the west coast is indicative of differential pattern of migration into coastal waters. While in Ponnani-Mangalore region the fishery starts early (August-September) and lasts longer (terminating in March-April), in Mangalore-Ratnagiri region it is of shorter duration commencing later (October-November) and terminating earlier (February-March) (Pradhan and Rao, 1958 Venkataraman, 1967). This indicates that the fishery starts first in the south and then extends north and the disappearance starts from north and then extends to south. Further investigations have to be carried out to find out whethere there is latitudinal migration in mackerel or whether these migrations refer to only incursion and excursion from offshore to inshore areas.

Water temperature and salinity seem to play a part in governing the migration of mackerel. Pradhan and Reddy (1964) noted the increase in temperature and salinity affected mackerel catches adversely, whereas their low values exerted less pronounced effect. Further, mackerel was observed to show higher susceptibility towards temperature variations than

to salinity. Higher pH may also have an added adverse effect on the fishery. Usually smaller size groups occur in good numbers only at a time (June-September) when the salinity and temperature are low. Bigger size groups show high tolerance towards increase in temperature and salinity as evidenced by the fact that larger ones (18-22 cm) occur in the period immediately following the monsoon followed by still larger specimens in the succeeding months (Pradhan and Reddy, op. cit.). However it is seen that bigger specimens can also withstand lower salinity and temperature, as evidenced by the occurrence of spawners and spent ones in the fishery during the monsoon months. But observations made in Vizhinjam did not show any direct correlation between the surface or atmospheric temperature and the duration and intensity of the mackerel fishery (Bennet, 1967).

At Karwar it was noticed that when there is wind in north-easterly direction, mackerel shoals enter the inshore waters and when there is strong wind in easterly direction mackerel shoals come close to the shore through deeper layers of waters. The shoals normally move along the current of water at high tide (Pradhan, 1956).

Three instances of mackerel migrating into estuarine waters have been recorded at Karwar, Mangalore and Cochin (Pradhan, op. cit.; George et al., 1959 and George, 1966). Mackerel ascend the estuarine waters of the Kali river at Karwar along the tidal current upto a distance of about 1½ miles during April and May when the range of salinity of river water is between 29.73 and 34.6 ‰. Further, the same author observes that instances of mackerel occurring in the Kali river in the rainy season when the salinity was as low as 2.04 ‰ have been reported. It was recorded in significant quantities in Netravati estuary, at Mangalore, during January-March, 1958 when the subsurface salinity in the zone of active mackerel fishery ranged from 14.10 ‰ to 23.50 ‰. It is significant that the fishery is supported mainly by a larger size group, compared to that of the catches obtained in the coastal centres. A similar migration was noticed in Cochin backwaters (salinity range 27.90 to 30.13 ‰) also during January-February, 1961 with the difference that samples of mackerel from the sea and the backwater showed similarity in the size pattern. Though no reason has been given for the migration into estuarine waters, the general abundance of pelagic fish populations including mackerel in the coastal waters might be the factor that influenced the entry at Cochin.

Tagging operations on some important pelagic fishes were recently carried out in Indian waters to study their migration and rate of growth (Hamre _et al._, 1966; Prabhu and Venkataraman, 1970). Tags used were loop tag, dart tag, semi-internal tag and opercular button tag. 2526 mackerel and 308 lesser sardine (_Sardinella gibbosa_) were successfully tagged and released off Marmgao harbour in December 1966 by the staff and trainees of the Central Institute of Fisheries Education, Bombay (Hamre _et al._, _op. cit._). Out of 2526 mackerel released, one was caught at Dona Paula about 15 km north of the place of release 8 days after tagging. The tagged fish moved north and shorewards and mingled with an untagged shoal.

Though a beginning was made at some places in 1966-67 season itself, large scale tagging covering several centres on the west coast and east coast was carried out by the staff of the CMFRI in 1967-68 on the Indian mackerel and oil sardine. A total of 290 mackerel was tagged and released in all the centres put together during 1966-67 season, of which only 4 were recovered from Karwar. The recovered specimens were caught near the vicinity of their release. The recovery rate here was comparatively high being 3.57%. 4122 mackerel were tagged and released during 1967-68 season. Of these, 23 were recovered, the overall recovery rate for the season being 0.56%. The centres from where mackerel could be tagged and released were Karwar, Calicut, Cochin, Vizhinjam, Mandapam and Waltair. The recoveries were nil at Karwar, though 3150 specimens were released there. Out of 345 mackerel tagged at Calicut, only one was recovered after two days about 3 km south east of the place from where it was released. The tagging experiments here only showed local movements. At Cochin, 460 mackerel were released after tagging and of this, 10 were recovered at places 16 to 55 km away from the place of release, the maximum time lapse being 50 days. Of the 10 recovered, 5 travelled towards south and 5 towards north. At Vizhinjam, only one mackerel was obtained out of 95 released and this was caught about 32 km north west of Vizhinjam on the day of its release. It showed that the fish travelled 32 km in a matter of few hours. The number released at Mandapam was 42 of which none was recovered. Out of 30 mackerel tagged and released in Lawson's Bay, Waltair, 11 were caught on the day of release itself in the same place.

In 1968-69 season, only 187 mackerel could be released after tagging, as the mackerel fishery was poor during the season. At Karwar, Cochin and Vizhinjam, 160, 23 and 4 fish were respectively tagged and released using mostly loop tags. Except for one fish, where recovery was reported from Vizhinjam, there was no other instance of tagged fish being caught in this season. The recovered specimen was obtained at Karunagapally, 19 km north of Vizhinjam, the number of days after liberation being 22.

The overall recovery rate for mackerel and oil sardine all the three seasons together came to 0.61% and 0.28% respectively. The low returns can be attributed to several factors such as initial tagging mortality and non-reporting of recovered specimens by fishermen. Based on the number of tags recovered and also judged from the point of causing least injury to the fish, it was seen that loop and opercular tags are comparatively better suited for tagging mackerel and oil sardine. Analysis of colour pattern of tags recovered showed that maximum recoveries were made in respect of red and blue colours.

The results obtained so far from tagging experiments show that the movements of mackerel and oil sardine were of two categories, one local moving near about the vicinity of their release and the other showing migration of a limited extent moving some distance north or south of the place of release. It is hoped that with the intensification of tagging programme, further knowledge will be obtained on the pattern of migrations of these commercially important pelagic species.

An interesting aspect of mackerel behaviour has been recorded by Devanesan (1942). He noticed that 10% of plankton obtained from Quilandy, near Calicut, was constituted by 'mackerel eggs', the rest being comprised of *Noctiluca*. From this he deduced that the mackerel preferred to spawn amidst inedible *Noctiluca* to ensure protection for their eggs from predators and better survival. But Prasad (1954) is doubtful whether mackerel exercises any choice on the selection of the spawning ground. He feels that this "may be an adaptation developed to certain by-products of the growth of *Noctiluca*".

4.4.2 Shoals

The size range of a mackerel shoal is very small and the individuals, as a whole show a remarkable similarity in size (Pradhan, 1956). This indicates that mackerel of different size groups move in separate shoals. They move in semi-circular or arrowhead formations and their speed is about 8 to 10 miles per hour. They scatter when pursued by seer fish. But when the shoals are chased by sharks or porpoises, the mackerel submerge with the head downwards into a compact mass. When the mackerels dive a patch of muddy water is seen at the surface which is due to churning of water by a large mass of fish.

Silas(1967b), while on a cruise on a dark night off Ratnagiri coast, noticed luminous mackerel shoals at about 16 F depth. The luminiscence was caused by mackerel shoals passing through a patch of phosphorescent zooplanktonic organisms which were abundant in the surface. He learnt that this phenomenon which makes the shoals more conspicuous, was not unusual off Ratnagiri coast and suggested investigations on the occurrence of such shoals all along the coast at such depths where purse-seining for mackerel can be carried out. Some aspects of mackerel behaviour such as the size of the shoals, direction of movement and swimming speed can be studied by making observations on mackerel shoals at nights aided by bio-luminiscence.

4.5 PARASITES AND PREDATORS

Numerous free solices of tapeworms or metacestodes were recorded in the plyoric caecae and the gut by Devanesan and John (1940). They further found just a few fully developed milk white tapeworms, some embedded in the peritorial tissue and some loose in the body cavity. The presence of free solices in the mackerel shows that it is the intermediate host of an adult tapeworm or tapeworms, the likelihood of permanent host being among sharks, porpoises etc. which are predators on mackerel. The occurrence of a fully developed tapeworm shows that the solices must have found their way into the body through the food of mackerel (Devanesan and John, op. cit.). Trematode, cestode and copepod parasites were recorded from Indian mackerel (Srivastava, 1936 a&b; Chauhan, 1945; Pillai, 1962; Rao, 1964a; Unnithan, 1964; Tripathi, 1957, 1962; Silas, 1967a; Silas and

Ummerkutty, 1967). Females of a new species of copepod parasite, Bomolochus jonesi has been described from the eye of the Indian mackerel (Bennet, 1968). Sharks, seer fish, ribbon fish and porpoises are predators on mackerel.

4.6 ABNORMALITIES

George *et al.* (1959) while examining mackerel specimens obtained from Netravati estuary at Mangalore found that unusually large number of specimens had sub-equal caudal fins, the lower lobe being shorter. They believe that this may be due to mutilation at an earlier stage of life or due to some pathological condition or even to some genetic factor. They, however, do not agree with the possibility put forward by the local fisherfolk that the lower caudal fin lobe might have been smoothly rounded off due to constant rubbing with the sandy bottom, for the reason the fin margins were not frayed nor did they show any trace of wear and tear.

Some abnormal specimens of *Rastrelliger kanagurta* from Indian coastal waters have been recorded by Jones and Silas (1964b). Some of them have an appearance similar to *R. brachysoma* and could be mistaken for it. The frequent abnormalities observed are listed below and these could be made out in the field itself.

"1) Short stumpy forms in which depth of the body is equal or greater than the length of the head.
2) The shortening of the portion of the body behind the second dorsal.
3) "Twisting" or curvature of the vertebral column in the caudal peduncular region.
4) Loss of one or more dorsal finlets due to injury.
5) Increase in the number of dorsal and anal finlets due to "twisting" of the caudal peduncular region.
6) Increase in number of first dorsal spines.
7) Short first dorsal fin" (Jones and Silas, *op. cit.*)

Another instance of occurrence of abnormal specimens of mackerel has been recorded by Bapat and Radhakrishnan (1968). Two abnormal specimens of total length 177 mm and 189 mm were collected from *Rampan* catches at Sashihittal, a fishing village near Kumta on the Canara coast. The body proportions showed appreciable variations, namely, body length/TL, maximum body depth along the pectoral fin/TL and maximum body depth along the anal fin/TL.

V. POPULATIÓN

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V. POPULATION

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5.1 STRUCTURE

5.1.1 Sex-ratio

Pradhan (1956) examining the mackerel landings at Karwar from 1948-49 to 1952-53 concluded that the sex composition of the commercial catches during the fishing season was roughly as 45% male and 55% female. Similar qualitative statements regarding sex distribution of commercial landings at various specific centres are available in the annual reports of the Central Marine Fisheries Research Institute. In 1965-66, the sex-ratio studies at Cannanore indicated that the proportion of males was slightly higher than females (53.18:46.32) in the adult population. The predominance of males was also seen in juveniles (modal size 135 mm). In the medium sized fish (modal size 205 mm) which contributed to the bulk of the catch, the sex-ratio was in the reverse order (40.7M:59.3F). In the same year, at Cochin females dominated the catches except for April and September (Central Marine Fisheries Research Institute Annual Report 1966). In 1966-67 season, the sex-ratio during the fishing season was found to vary though in some centres it was almost equal (Central Marine Fisheries Research Institute Annual Report 1967). In the first half of 1967-68 season, the sex-ratio of a sample analysed at Karwar showed that females were more numerous. At Mangalore, males were more numerous in the aggregate. Sexes were almost equally represented at Cochin and Cannanore. At Vizhinjam males were predominant in March. In the second half of the year, at Cannanore the females increased to more than twice that of males (Central Marine Fisheries Research Institute, Annual Report 1968). The above excerpts will show that there is no uniformity in the sex distribution in the commercial catches either among various centres or between various fishing seasons. In the absence of a statistical analysis of data collected at different centres in different seasons, it is difficult to arrive at any firm

conclusions. It is necessary that a composite statistical analysis to study the variation in sex-ratio based on data collected at various centres over several seasons should be carried out with particular reference to the size of the fish, the state of maturity of the fish as also the month of capture.

The sex-ratio distribution of samples collected at Cochin over 24 months during 1968 and 1969 was subjected to statistical analysis. The percentages of males as derived from the monthly samples varied from 42.10 to 70.00. But statistical analysis did not show significant departure from the 50:50 ratio among males and females. Similarly, the sex distribution among different sizes ranging from 115 mm to 255 mm was also studied. The sample ratio of males varied from 28.57 to 75.00, but the overall percentage of males of overall sizes was 51.50. Statistical test of sex-ratio among different size groups did not show any significant departure from homogeneity. The observed sex-ratios in different size groups were not found to be significantly different from the hypothesis of equality of sex-ratio.

5.1.2 Size and age composition

The commercial fishery begins to exploit mackerel from about a size of 18 cm. Fish below this size are also caught in good numbers in some places. The following table summarises the percentage of fish of different sizes caught at various places.

Percent of fishes caught in various size groups

Place	Up to 18 cm (upto 6 months)	18-22 cm (6-12 m)	22-24 cm (12-24 m)	24-26 cm (24 m & above)
1. Karwar (Average of 1948-49 to 1965-66)	4.19	74.12	19.53	2.16
2. Mangalore (1958-59 to 1965-66)	31.01	52.34	14.99	1.66
3. Cannanore (1960-61 to 1965-66)	47.08	49.39	3.45	0.08
4. Calicut (1957-58 to 1965-66)	24.69	66.59	8.60	0.12
5. Cochin (1962-63 to 1966-67)	79.90	18.76	1.32	0.02

It will be seen from the above table that about 80-90 per cent of fish in the commercial catch comes from size below 22 cm. The size groups above 22 cm contribute a small portion in the commercial catch. Several interesting facts emerge if the data are carefully examined. The contribution of fish below 18 cm in the commercial catch in Cochin was the highest and that in Karwar was the lowest. In general the percentage of fish below 18 cm in the commercial catch was higher in Kerala than in Mysore. The very high percentage of below 18 cm fish in Cochin catch may be due to the use of small meshed "Thangu vala". The preponderance of below 18 cm fish in Kerala State as a whole may be due to the early appearance of juveniles in these waters. The season in Karwar starts 2-3 months later than in the south and this may explain the low percentage of 10-18 cm group in the catch. The percentage of above 22 cm fish in Mysore catch is higher than in Kerala. On the assumption of only one stock contributing to the fishery both in Kerala and Mysore, it is difficult to explain this divergence. If, however, Mysore stock is different, the above fact can be explained in terms of differential mortality arising out of the fact that fishing starts at a higher size in the State. It is necessary to study if there are more than one stock contributing to the mackerel fishery in the west coast of India.

Regarding age and size relation, there are divergent opinions. If it is assumed that the fish attains a size of about 22 cm in the first year of its life, it will be seen that the major contribution to the commercial catch comes from the 0-year class. The 1-year and 2-year classes contribute progressively less. Hence the prospect of a fishery in any year will mainly depend on the strength of availability of the 0-year class. It will not be out of place here to note that the assumption of very fast growth in the early part of the life of the fish so that it attains a length of 22 cm at 1-year will be in accordance with the fact that less number of below - 18 cm fish are caught in Karwar where the fishing starts 2-3 months later - this interval allowing the fish to grow beyond 18 cm size.

5.2 SIZE AND DENSITY

5.2.1 Average size

If F is the fishing mortality in any year, and Y_w is the yield (by weight), then $\frac{Y_w}{F}$ will estimate the average stock in weight or average biomass of the fish stock during the year. Similarly, if Y_n is the yield in numbers $\frac{Y_n}{F}$ will represent the average size of the stock in numbers. The fishing mortality F is assumed to be proportional to fishing intensity i.e. F = qf where f is the fishing intensity and q is a coefficient of proportionality called catchability coefficient. Thus catch per unit of fishing intensity is proportional to the average abundance of stock (either in number or in weight). Thus if an estimate of the catchability coefficient q is obt obtained, estimates of F for different years can be obtained, based on which the average stock size or average biomass of the stock in different years can be obtained. There are no published materials regarding such studies. The main reason for paucity of such studies may be due to the employment of several types of gear, leading to difficulty in arriving at estimates of effort in terms of some standard unit. The fact that rampani net forms the major gear in the exploitation of mackerel in the Mysore waters while various types of boat seines and gill nets are used in the Kerala waters without much overlapping makes the problem of standardization of effort a formidable one.

Even if it is possible to get estimates of effort in standard units, it is doubtful whether for a pelagic fish like mackerel which is exploited only when it is available in the inshore waters, it will be correct to determine the size of the stock from the catch and fishing mortality data. The availability of the fish in the inshore waters may change due to several factors and such availability change will introduce serious biases in mortality rates if they are estimated from the catch per unit effort data.

Sekharan (1958) has stated that "The fact that the fishery is supported mainly by a single age-group cannot be explained in terms of selective action of the gear, at least as far as the rampanis are concerned. These nets touch the bottom of the area fished, and their

catches include young forms of other species measuring 3-4 cm and even less; similarly, larger specimens having a length of 100 cm or even more have also been recorded from their catches. As there is little intermingling of the age-groups within the range of waters fished during the months October-March, the average catch-per-unit-of-effort of a season would perhaps form an index of the relative numerical strength of the year-class concerned. But the availability of the fish in the normal fishing grounds, especially in those situated very near the shore, might be limited by a number of factors. Hence, estimates of the relative numerical abundance of year-classes based on the statistics of the coastal fishery, are, as likely as not, to be correct. On the other hand, the more offshore fishery off Malabar which samples the population more evenly might yield useful data on this point.

5.2.2 Changes in density

It has been stated in the preceding sub-section that the catch per unit effort is proportional to the true density of the stock. Hence changes in density can be studied by examining the fluctuations in the catch per unit effort figures. But apart from density of stock, many factors like changes in availability may affect the estimates of catch per unit effort. Even in case of some gear like drift net, as the meshes of the net fill up with fish, the chances of capture decrease and so the catch per unit of effort decreases as an index of stock as the density of fish increases. This effect has been named "gear saturation". Weather conditions and behaviour of fish are also among factors influencing the catch per unit effort. For example, Sekharan (1965) studying the mackerel fishery in Mandapam area has shown that the night hauls gave a much higher catch-per-unit-effort than day hauls, though the average length of mackerel in night catches was slightly smaller.

The table below gives the catch per unit effort in various fishing seasons at some of the centres: for reasons stated above, the unit of effort at different centres was different and as such though the data are not comparable between places, they are comparable between different years. The name of the effort unit for each place is also given in the table.

Table showing catch per unit éffort of mackerel

Years (July-June)	Catch (kg) per unit effort				
	Karwar (piece of Rampan)	Calicut (Ayilachala vala)	Cannanore (Ayilachala vala)	Mangalore (Pattavala)	Cochin (Thanguvala
1950-51	46.62	-	-	-	-
1951-52	34.15	-	-	-	-
1952-53	28.13	-	-	-	-
1953-54	31.46	-	-	-	-
1954-55	19.56	41.55	-	-	-
1955-56	10.11	33.87	-	-	-
1956-57	10.67	41.24	-	-	-
1957-58	47.42	48.65	-	-	-
1958-59	31.35	54.37	-	180.69	-
1959-60	-	35.90	-	58.63	-
1960-61	28.90	72.59	101.39	93.08	-
1961-62	2.76	38.49	110.27	100.22	-
1962-63	10.84	103.53	112.59	143.34	21.55
1963-64	11.05	75.70	119.78	108.80	1.30
1964-65	11.94	74.62	153.26	100.54	3.02
1965-66	2.76	75.68	132.90	22.91	5.60

It will be seen from the above table that the catch per unit effort in Karwar was more or less of the same order during the 4-year period from 1950-51 to 1953-54, then it declined during the next three year period from 1954-55 to 1956-57, it again went up in 1957-58 to 1960-61 and then had a precipitous fall in the subsequent years. The trend of fluctuations in the catch per unit effort more or less follows the fluctuations in annual catches given in the following table. However, in other places there is no such correspondence between the catch-per-unit-effort and the relevant regional catch. It is necessary to investigate whether the introduction of nylon nets displacing all other types of indigenous gear of cotton fibre on the Kerala and South Mysore coasts has been instrumental in increasing the efficiency of the nets thereby inflating the catch-per-unit-effort. It is needless to emphasize that in studying changes in stock density, it is necessary to take into account any changes in the efficiencies of the gear due to improvement in design or fabricating material so that catch-per-unit-effort can effectively be considered as indices of stock density.

Table showing State-wise landings of mackerel (m.tons)

Season: July-June	West coast Kerala	Mysore	Maha-rashtra	Total	East coast total	Grand total
1950-51	51,998	15,035	3,099	70,132	1,987	72,119
1951-52	71,852	36,147	9,523	117,522	3,664	121,186
1952-53	15,337	36,737	11,685	63,759	544	64,303
1953-54	5,541	36,421	11,938	53,900	472	54,372
1954-55	8,938	13,699	4,258	26,895	1,302	28,197
1955-56	4,252	12,466	4,044	20,762	2,498	23,260
1956-57	12,784	5,552	4,724	23,060	2,608	25,668
1957-58	38,350	63,320	1,597	103,267	1,238	104,505
1958-59	59,256	73,792	7,729	140,777	1,105	141,882
1959-60	9,744	15,038	316	25,098	3,877	28,975
1960-61	42,479	77,723	12,443	132,645	2,374	135,019
1961-62	8,321	7,129	22	15,472	8,629	24,101
1962-63	14,424	12,441	1,974	28,839	1,820	30,659
1963-64	47,493	19,115	4,612	71,220	6,397	77,617
1964-65	16,873	19,480	2,807	39,160	2,179	41,339
1965-66	9,191	3,971	9	13,171	3,139	16,310
1966-67	10,470	6,510	180	17,160	6,784	23,944
Average	25,135	26,740	4,762	56,637	2,978	59,615
Per cent	42.16	44.85	7.99	95.00	5.00	100.00

5.3 NATALITY AND RECRUITMENT

The data on the relative strength of the various size groups in the commercial catch are available for two centres in Mysore State and three centres in Kerala. But data on relative strength of various size groups for the entire range of fishery are not available, obviously because of the difficulty of obtaining estimate of effort for the whole region in terms of standard unit. On the basis of current opinion of age-size relation, the data on relative abundance of size groups available for the five centres could be expressed as relative abundance of various age groups. As fluctuations in the commercial fishery are mainly caused by changes in the abundance of the 0-year class, correlation between the abundance of the newly recruit class and catch would not be much helpful towards predicting fishing success. It is, therefore, necessary to undertake detailed studies on the abundance of pre-recruit phase which will ultimately influence the natality and the recruitment in the exploited phase. Another avenue of studying the recruitment problem lies in finding out the relationship between parent stock and subsequent

recruitment - one of the hardest problems in fisheries biology to solve. Two sorts of data required are lacking viz., (1) long-term series of estimates of stock and recruitment, and (2) a range of measures of larval and juvenile mortality at sea. Both sets of data are required to understand the nature of compensatory mechanism. It is likely that the essence of the mechanism is a form of density - dependent mortality. A proper understanding of this mechanism can only explain the fluctuations in the recruitment in the exploited phase.

5.4 MORTALITY, MORBIDITY ETC.

Banerji (1967) has shown that in spite of variations in the levels of abundance of mackerel from year to year at Karwar, the instantaneous rate of decrease remains constant. Since the mackerel fishery depends mainly on one age group, this furnishes an estimate of instantaneous total mortality, the best estimate of which was found to be 0.64 on a monthly basis. Since the fishing season is for a period of 6 months only, the estimate for instantaneous annual mortality rate will be about 2.64. Based on the relative abundance of various age groups in the commercial catch at Karwar for the period from 1948-49 to 1965-66, Banerji and Krishnan (MS) has estimated that the annual instantaneous mortality rate varied from 0.86 to 4.55 with an average of 2.06 which is not far from the estimate obtained by Banerji (op. cit.) earlier by a different method. By plotting the annual estimates of annual mortality rates against annual effort, Banerji and Krishnan (op. cit.) obtained the estimate of natural mortality rate as 0.65. These estimates are only tentative and have to be compared with similar estimates to be obtained from the data of other centres.

Instances of mass mortality of mackerel are not recorded though one such doubtful reference relates to the reports of enormous quantity of mass mortality in the Arabian Sea between 55-70°E and 10-25°N in 1957 and 1958. It was estimated that the quantity involved was over 20 million tons of fish. Jones (1964) has listed the various reports from commercial ships regarding this phenomenal mass mortality of fish in the Arabian Sea and considering the size and the area of occurrence of the reported mass mortality, he is of the opinion the fish involved might have been juvenile tunas, though according to Kesteven quoted by Prof. S. Rass of

the Institute of Oceanology, Academy of Sciences U.S.S.R. in personal communication to Jones, the fish involved might have been Rastrelliger or Scomberomorus.

5.5 DYNAMICS OF POPULATION

5.5.1 Population parameters

One of the fundamental problems is to determine the effect of fishing on the fish stock and to determine the level of fishing intensity that will fetch the maximum yield on a sustainable basis. This leads to deriving mathematical model linking yield to various population parameters of growth, recruitment, natural and fishing mortality rates. Having obtained estimates of parameters of growth and natural mortality either from data on catch and effort or from capture - recapture data, the curve for yield-per-recruit in relation to variation in fishing mortality is drawn from which estimate of maximum yield per recruit corresponding to associated level of fishing mortality is obtained.

Work on estimation of the various population parameters has just been initiated with regard to mackerel. By considering the monthly length frequency distributions of fish samples at different places from data collected over several years, and plotting the modal values of different broods in a sequential order, it has been possible to obtain the average size attained by the fish at the end of successive months of the life of the fish. Fitting Bertalanffy's growth equation to these data, Banerji and Krishnan (MS) obtained estimates of the three parameters l_{oo}, k and t_o for the five centres as follows:

Place	Estimates of growth parameters		
	l_{oo} (mm)	k	t_o (months)
Cochin	222	0.40	+ 0.85
Calicut	233	0.26	- 0.06
Cannanore	226	0.36	+ 0.64
Mangalore	228	0.42	+ 1.85
Karwar	229	0.41	+ 2.05
West coast	235	0.26	+ 0.35

The analysis of covariance showed that there was no significant difference among the growth equations obtained from the data at five centres and a pooled growth equation for the west coast was obtained. The estimates of the parameters in the pooled growth equation are also given above.

It has already been stated that the natural mortality M has been estimated at 0.65. Taking the minimum age of capture at 0.25 years, Banerji and Krishnan (MS) has found that maximum yield per recruit will be obtained at effort corresponding to the fishing mortality rate of F = 1.55 as compared to the currently employed average intensity corresponding to F = 1.40. This shows that we are almost exerting the maximum effort and are nearer to the optimum yield and further increase in fishing intensity in the inshore fishing area exploited at present may fetch only marginal increase in catch.

In this connection reference may be made to Banerji and Chakraborty (196) who defined the ratio of unweighted index of abundance to the weighted index of abundance to be a measure of fishing efficiency and have shown that the regression coefficient of unweighted index to the weighted index provides the best estimate of fishing efficiency. By using catch per unit of effort data from Karwar from 1948-49 to 1958-59, they have shown that the fishing efficiency was not significantly different from 1, indicating that the fishing efficiency was not significantly better than what would have been in the case of random fishing. Discussing if this inefficiency is due to the inability of the fishermen to detect the periods of high abundance and exploit them at the time or due to some other reasons, the authors attributed this inefficiency to inadequacy of transport, marketing facilities and other economic factors. This would indicate the bias introduced in taking catch per unit effort as index of stock abundance and in using it in estimating mortality rates. This aspect needs further investigation.

5.5.2 Length-weight relationship

The total instantaneous mortality rates are estimated by comparing relative abundance of consecutive age-groups in adjoining years. The relative abundance of various age groups is generally obtained from the

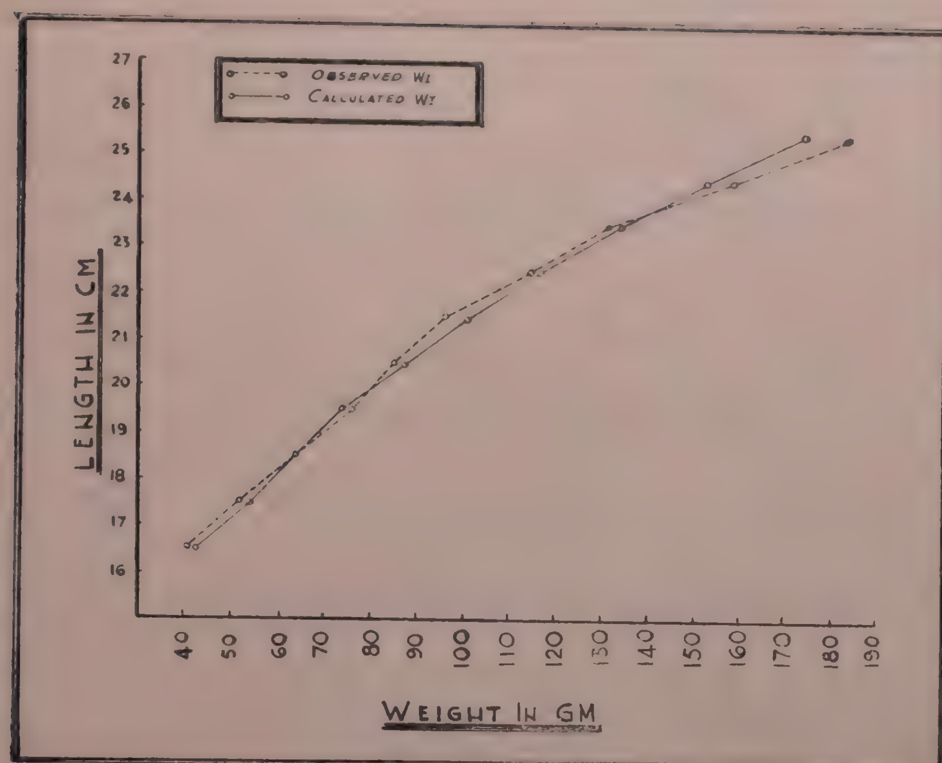

Fig. 7. Length-weight relationship of ***Rastrelliger kanagurta*** (Reproduced from Pradhan, 1956).

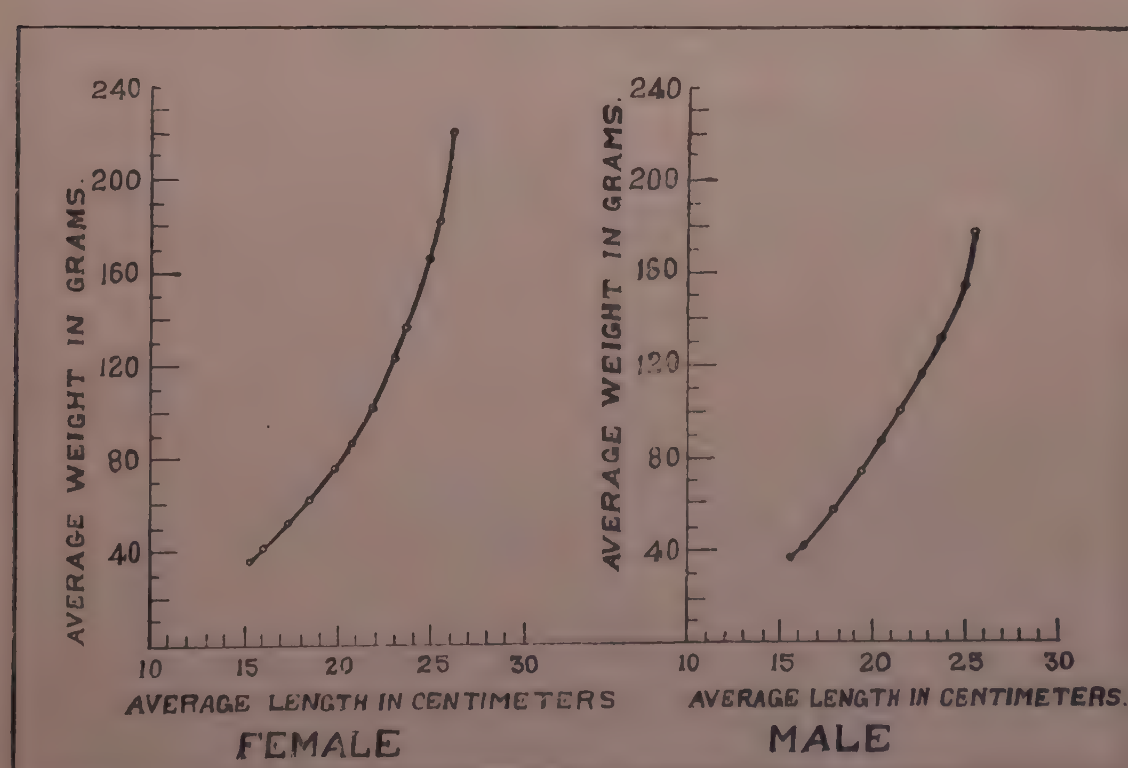

Fig. 8 Average observed length and weight of ***Rastrelliger kanagurta*** for male and female (Reproduced from Pradhan, 1956).

relative abundance of various size groups. As the commercial catch is generally given by weight, it is necessary to convert them into numbers for the purpose of estimating the relative abundance of various size groups. A general relation between length and weight is useful for the purpose. Often statistical studies are necessary to find out if there are significant difference between the relations obtained in different areas or in different years.

Sometimes the length-weight relationship studies have been profitably used to discriminate between different independent stocks.

Pradhan (op. cit.) on the basis of a sample collected at Karwar between 1948-49 and 1952-53 of 1250 specimens of mackerel ranging in size between 12 and 26 cm total length obtained the length-weight relation as $W = 0.005978\ L^{3.1737}$. He did not furnish the standard error of the estimates of two parameters in the length weight relation (Fig.7 & 8).

Sekharan (op. cit.) studying the mackerel in Mandapam area gave the following relations in respect of day and night landings.

Day : $\text{Log } W = \overline{6}.2161 + 3.3390 \log^{L}$

Night : $\text{Log } W = \overline{6}.5662 + 3.1571 \log^{L}$

He also showed that there is no significant difference between the two relationships. Jones and Silas (1964b) obtained for Andaman mackerel R. kanagurta the relation as $\log W = \overline{6}.4610 + 3.3087 \log^{L}$.

5.6 IDENTITY OF SUBPOPULATIONS

A species can comprise a single stock or a number of stocks. Each stock has often a fixed spawning ground with a specific spawning season and probably a consistent migratory circuit. Spawner of one stock does not leave the stock or join others from other spawning grounds to any great extent from year to year. From the point of fisheries management, identification and delimitation of constituent stocks of a species is very important in as much as different fishing intensities may be employed to different stocks, resulting in varied management policies for the individual stocks. Practically no attempts have been made so far to find out if the mackerel fishery on the west coast of India is based on a single homogeneous stock or on a number of independent stocks. A programme of

taking exhaustive measurements on a number of morphometric characters and counts on meristic characters on samples of fish from different localities was undertaken in the Institute several years back. No publications on the statistical analysis of these measurements are, however, available. If the voluminous data collected are subjected to statistical analysis by employing discriminatory or distance functions, the results will be interesting. The small amount of recoveries made from the large scale tagging and liberation of mackerel during 1967-68 show that all the recoveries were made around the centres of liberation and not a single instance of interzonal recovery was made - a phenomenon that would tend to indicate the existence of a number of independent and discrete stocks, though categorical assertion on this would not be justified based on the very small number of recoveries (Prabhu and Venkataraman, 1970). Apart from capture - recapture data and statistical analysis of morphometric and meristic characters, biochemical methods can also be profitably employed in differentiating stocks.

5.7 RELATION OF POPULATION TO OTHER FISHERIES

It is well-known that the geographical range as well as the fishing season of the mackerel and oil sardine fishery on the west coast of India broadly coincide and the two fisheries form the mainstay of the pelagic fisheries of the west coast. In the beginning of this century, Hornell (1910b) observed that the fishing success of the one species is inversely correlated with that of the other in the sense that scarcely ever both the species were abundant in the same year and a good year for one generally coinciding with an unsuccessful fishery for the other. Nair and Chidambaram (1951) on the basis of landings data of 24 years from 1925-26 to 1948-49 compiled from fish-curing yard records agreed with Hornell regarding the existence of an inverse relationship between the fishing success of these two fisheries.

The following table furnishes the estimated landings of mackerel and oil sardine separately for Kerala and Mysore from the 1950-51 to 1968-69 seasons (based on Central Marine Fisheries Research Institute survey).

Comparative figures of landings (tonnes)
of mackerel and oil sardine in Kerala and Mysore

Season	Kerala		Mysore		Kerala-Mysore	
	Mackerel	Oil sardine	Mackerel	Oil sardine	Mackerel	Oil sardine
1950-51	51,998	12,442	15,035	1,643	67,033	14,085
1951-52	71,852	19,545	36,147	1,855	107,999	21,398
1952-53	15,337	27,664	36,737	10,201	52,074	37,865
1953-54	5,541	19,519	36,421	2,762	41,962	22,281
1954-55	8,938	41,306	13,699	6,648	22,637	47,954
1955-56	4,252	14,196	12,466	837	16,718	15,033
1956-57	12,784	20,175	5,552	2,141	18,336	22,316
1957-58	38,350	243,393	63,320	5,746	101,670	249,139
1958-59	59,256	74,949	73,792	542	133,048	75,491
1959-60	9,744	32,163	15,038	2,970	24,782	35,133
1960-61	42,479	260,508	77,723	2,734	120,202	263,242
1961-62	8,321	91,181	7,129	6,006	15,450	97,187
1962-63	14,424	115,644	12,441	10,091	26,865	125,735
1963-64	47,493	47,241	19,115	8,523	66,608	55,764
1964-65	16,873	281,548	19,480	77,742	36,353	359,290
1965-66	9,191	157,930	3,971	40,261	13,162	198,191
1966-67	10,470	233,614	6,510	53,841	16,980	287,455
1967-68	4,216	204,318	14,944	11,414	19,160	215,732
1968-69	3,877	235,545	5,784	68,682	9,661	304,227
Average	22,916	112,257	25,016	16,560	47,932	128,817

In comparing the failure or success of a fishery, it is necessary to fix some yardstick which will provide the basis for such measurement. One such yardstick is provided by the average annual catch of each species. On the basis of this yardstick, if we compare the annual landings of mackerel and oil sardines in Kerala for the 19 year period, we find that out of 19 years, there were two years when both oil sardine and mackerel landings were above annual average; and 7 years when the landings of the species were below annual average; in the remaining 10 years the mackerel landings alone exceeded the annual average in 4 years and the oil sardine in 6 years. In Mysore, out of 19 years, the landings of both the species in 9 years were below their respective annual average catches, while in 6 years the mackerel landings exceeded the annual average and in 4 years the oil sardine landings exceeded its annual average. Taking both States together, we find that there were 7 years when the landings of both the species were lower and 2 years when the landings of both were greater than their respective annual average and in the remaining 10 years, the

mackerel landings were better than average in 5 years and oil sardine landings better than average in another 5 years. Thus measured against the yardstick of annual average, no definite inverse relationship in the fishing success of the two species as averred earlier was discernible. Only in about half the number of years, there are indications of inverse relationship. Since the range of variability of the annual landings of the two species may differ, it may be argued that the variability also should be taken into consideration along with average in providing a yardstick for comparison. This is done by dividing the difference of a year's landing from the average by the standard deviation. Comparing the two sets of transformed data thus obtained, no significant negative correlation was obtained to sustain the hypothesis of inverse inter-relationship between the abundance of the two species.

The annual catch of both the species exhibits wide fluctuations. In case of mackerel, the annual landings varied from 9,661 to 133,048 tonnes with an average of 47,932 tonnes. The coefficient of variation is about 81%. In case of sardines, the annual landings varied from 14,085 to 359,290 tonnes with an average of 128,817 tonnes and coefficient of variation of about 89%. Thus in both the fisheries the magnitudes of variations are more or less of comparable order at least for the 19 year period from 1950-51 to 1968-69. Since the magnitude of variations are of comparable order, if clear-cut inverse relationship between the annual landings was found, one would have easily explained the phenomenon in terms of competing species in a multiple fishery eco-system. Eventhough this aspect of competition cannot be ruled out altogether, probably many other factors interact to cause such variations in abundance of the two species that could not be explicitly expressed in terms of simple inverse inter-relationship.

VI. EXPLOITATION

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VI. EXPLOITATION

K.V. Narayana Rao

6.1 FISHING EQUIPMENT

The types of fishing craft and gear commonly used in the fishery have been evolved to suit the local requirements depending upon the physical characteristics of the coastline, surf conditions as well as habits of fish. Descriptive accounts of the types of these craft and gear, used both on the west and east coasts of India, are given by Hornell (1910a and 1938), Chopra (1951), Anon. (1941 and 1943), and Zeiner and Rasmussen (1958). Later Jones and Rosa (1965 and 1967) have listed the important types of fishing craft and gear commonly employed in the mackerel fishery. Similarly Rao (1969) has shown, among other things, the most common types of fishing boats and nets used in the Indian waters for this fishery.

6.1.1 Fishing craft

The craft that are employed in the mackerel fishery of India, are known by various names along the different sections of the coastline, and can be classified essentially into four basic types based on their constructional features (Table I). A short description of the more important craft viz. dug-out canoes and built-up canoes or canoe boats is given below.

Dug-out canoes: As the name implies, it is made by scooping out from a single log of wood, of either Mango (*Mangifera indica*) or Jarmal (*Tetrameles nudiflora*) or Jungle Jack (*Artocarpus hirsuta*). The keel portion is kept thicker than the sides. The free board is raised by a strake of planking of teak (*Tectona grandis*). The dug-out canoe, although the most commonly employed fishing craft along the west coast, reigns supreme only along the Kerala coast where two types of it are extensively used. A bigger dug-out canoe called Odam or Vanchi measuring 9.8-10.7 m long,

0.9 m wide and 0.8 m deep and of 3-5 ton displacement is usually employed for operating bag nets; and a smaller type, called Thoni with dimensions 7.3x0.9x0.8 m and 2 ton capacity used for drift net, gill net and cast net fishing (Anon., 1943). The latter type is commonly used along the Canara and Konkan coasts also where they are called either Thoni or Pagar (Chopra, 1951). None is provided with rudder; steering is effected by means of a big paddle used for propulsion as well as control. Few have sail; when they do have, it is either a small square one or a sprit sail (Zeiner and Rasmussen, 1958).

Built-up canoes or canoe boats: On the Canara and Konkan coasts, along with dug-out canoe, special type of flat-bottomed outrigger boats are used exclusively for the operation of Rampani net. These boats, known as Akada Hody in Konkan and Pandi along the Canara coasts, are nothing but the widened copy of west coast Dug-out, built up of planks of teak wood (*Tectona grandis*). In size these boats range from 6 to 12 m in length, 0.7 to 2.4 m in beam and 0.9 to 1.2 m in depth; and are provided with a rudder fitted to the stern post by lashings. Stern to stern they are curved at about the usual angle adopted in dug-outs (Zeiner and Rasmussen, 1958). The basal part of the hull of these boats may consist either of a dug-out region with low vertical sides or of three planks - a bottom plank and two narrow vertical side planks rabbeted to the edges of the basal one. In both cases the sides are spread out until they attain a distinct flare. On these flared edges a series of strakes, in turn flaring outwards, is added in order to give necessary freeboard. No mast is carried as the boat is rowed as the net is shot.

The boat is rigged with an out-rigger to give stability. The out-rigger is formed of two bamboo booms and a wooden float. Proximally the booms cross the hull several feet apart and are so tied to the gunwales that the distance between their distal ends decreases. The booms distally extend outboard about 1.5 to 1.7 m and to their distal ends is directly attached a light wooden float made of Maruka (*Erythrina indica*).

Formerly these boats were reported to be of 4.9-6.1 m long (Hornell, 1938 and Anon., 1943). But in recent years they are much bigger, measuring 12.2-13.7 m (Pradhan, 1956; Zeiner and Rasmussen, 1958).

Table I

Common types of fishing craft employed in the mackerel fishery in India

Region	Basic types of fishing craft			
	Dug-out canoes	Built-up canoes or canoe-boats	Plank built boats	Catamarans
1. Maharashtra	Pagar Thoni	Akada Hodi	-	-
2. Mysore	Thoni	Pandi	-	-
3. Kerala	Odam Thoni	Vallam	-	Kattumaram
4. Tamil Nadu	-	-	Vallam (Tuticorin-type boat) Padagu (Masula boat)	Kattumaram Periamaram Chinnamaram
5. Andhra	-	-	Padava (Masula boat)	Theppalu
6. Orissa	-	-	Ber (Masula boat)	-

6.1.2 Fishing gear

Surveying the fishing methods of the Malabar and the Coromandel coasts, Hornell (1927 and 1938) has given, *inter alia*, a detailed description of the fishing gear and the methods employed in the mackerel fishery of those regions. Similar but concise information on the subject is also available from the accounts of Anon. (1941 and 1943) and Chopra (1951). Jones and Rosa (1965 and 1967) have also mentioned the most important types of gear employed in the fishery both in India and elsewhere. In the following table are given such of the common types of gear in which mackerel are caught. A short description of these common gear is also given based on the earlier works mentioned above.

Table II

Common types of fishing gear employed in the mackerel fishery of India

Region	Basic types of fishing gear				
	Bag nets (Boat seines)	Drag nets (Beach seines)	Gill nets	Drift nets	Cast nets
1. Maharashtra	-	Rampani Payawada	Bangada Jal	Pettle bale	Pag
2. Mysore	Kolli bale Paithu bale	Rampani Yendi or Kairampan	Patta bale Chala bale Kantha bale Ida bale	Kandadi bale	Deb bale
3. Kerala	Ayilakolli vala Pattenkolli vala Arakolli vala Odam vala Paithu vala Nethal vala Thangu vala Madi vala	Kara madi Kara vala	Ayilachala vala	Ozhuku vala Noo vala Vangada vala	Veechu vala
4. Tamil Nadu	Thuri valai Mada valai Eda valai	Kara valai Peria valai	-	Vazhi valai Vala valai	-
5. Andhra	Iraga vala	Pedda vala	Oddi vala	-	-
6. Orissa	Iragalai vala	Ber Jal	-	-	-

As can be seen from the Table II, there is a variety of gear deployed in the mackerel fishery. Although they go by different names in various sections of the coastline, all of them can be classified into five basic types namely, boat seines, beach senies, gill nets, drift nets and cast nets, depending on the design and mode of operation. It may be mentioned, however, that among the various types of the gear employed in the fishery, the most important ones are the Rampan, Ayilakolli, Pattenkolli, Arakolli, Paithu vala, Madi vala and Ayilachala vala on the western seaboard, and Peria vala or Pedda vala and Vazhi vala on the eastern side. Further Ayilakolli vala, Pattenkolli vala and Arakolli vala are in fact the same type of boat seines, varying only in size of the net and mesh. So also is the case with Odam vala, Paithu vala and Madi vala of Kerala and Kolli bala and Paithu bala of South Canara. Similarly the

Thuri valai of the Coromandel coast, Iragavala of Andhra and Iragali jal of Orissa are one and the same type of nets.

In the following account descriptions of Ayilakolli vala, Rampani and Ayilachala vala are given as representing important types of gear based on the reports of Hornell (1927 and 1938), Anon. (1943) and Chopra (1951).

Ayilakolli vala: It is a boat seine, specially designed for capturing mackerel, as the name implies. The Ayilakolli vala has the same general design as that of Odam vala but differs from it in two or three important constructional details: (1) The wings, here are quite short, about 1/3 the length they have in Odam vala, (2) Except for the peripheral section consisting of 1.83 m broad cotton netting, the bag is made of hemp twine with rather large mesh in contrast with small-meshed cotton twine bag of Odam vala and (3) The platform or "kolli" and its sides in Ayilakolli are of cotton netting of small mesh instead of large-meshed coir of Odam vala. Because of these features, Ayilakolli vala can be operated more easily and efficiently making it the most versatile. It has a bag 10.98 m long and a platform measuring 21.96 m. The wings, one on either side of the platform or "kolli" are rather short, measuring 14.64 m. The mesh of the bag varies from 15 mm at cod end to 25 mm at the mouth; while the mesh of platform also measures 25 mm.

The net is operated from a pair of odams with a crew of 7-8 men. Each canoe carrying half the net, they sail to the fishing ground and when a shoal is sighted the canoes separate and the net is shot across the path of the shoal. The lead line is short and the float line is set far back. The wings and the net are well stretched by paddling the canoes. By adjustment the lead line is allowed to sink below the level of the shoal and the head rope is kept afloat above the level of the shoal. As soon as the encircled shoal passes over the platform and towards the mouth of the bag, the canoes converge. The wings are hauled till the lead line comes above the surface, thus driving the fish into the bag. By hauling the float line vertically the catch is concentrated at the cod-end which is then lifted up between the canoes. The catch is emptied into one of the canoes and the boats move out for the next operation.

According to Antony Raja (1969) the kollivala of cotton has yielded to that of nylon twine in the major portion of Kerala coast and is operated as Pattenkolli vala. This net was in fact introduced at Calicut towards the end of 1956 and is being intensively used since then at Calicut, whereas its extensive use along the major portion of the Kerala coast needs verification, for no reference is made about this net at other major centres along Kerala coast so far. As Pattenkolli combines features both of Ayilakolli and Mathikolli, it is used effecitvely for capturing both mackerel and the oil sardine and is likely to become popular with the fishermen in due course all along the coast. The net is reported to be larger than either Ayilakolli or Mathikolli, for it measures 25-30 m, of which the bag itself occupies half of the length. The mesh of the bag varies from 10-14 mm at the cod end to about 22 mm at the mouth of the bag; so much so its versatility in capturing both the oil sardine and mackerel with great efficiency is obvious.

Rampani: This is a bagless beach seine of splendid catching power. It is believed to have been introduced in Canara coast about a century ago by a Portuguese parish priest, Father Rampani, and hence is appropriately named after him. Today it is extensively used both along the Canara and southern part of Konkan coasts. It is a very large beach seine, made of hemp (Crotalaria juncea) and of varying size. In a typical case, it consists of 100 pieces laced together; each piece measuring 11 m long, breadth varying from 7 m at the centre to 2 m towards the ends and with mesh size ranging from 30 mm at the ends to 12 mm at the centre of the net. The head rope of the net is buoyed with wooden floats and the foot rope is weighted with stone sinkers at regular intervals.

The net is operated only when a sizeable shoal of fish is noticed coming close enough to warrant its operation. On each such occasion, the net is carried, piled up in a Pandi or Hodi, leaving one end on the shore. As the net is paid out the boat takes a semi-circular course and when the last of the net is out enclosing the shoal, the boat brings back the other end of the net to the shore to a point far away from the starting point. The net is slowly dragged by a party of 40 men on each side and as the net approaches the shore, the two parties come closer and closer. The catch is finally either brought ashore or is impounded in the foreshore waters as the situation demands.

The Payawada and Yendi or Kairampan are nothing but smaller versions (80-120 x 5 m) of rampani and are operated during the rainy season and also to remove the impounded mackerel from rampani net.

Ayilachala vala: It is a gill net made of cotton twine and is designed especially for mackerel, and is reported to be exactly similar to Patta bale of South Canara both in design and operation. The net is operated from two small canoes (Thoni) manned by a crew of 2-4 in each. Each net section usually measures 14.6-21.9 m long and 9-11 m deep withh a mesh of 25 to 55 mm. The two canoes carry aboard 6-9 such pieces laced together end to end. The head rope of the net is provided with wooden floats at regular intervals and similarly the foot rope is weighted with stone sinkers.

Leaving the shore the crew reach the fishing ground and look for the indications of shoals. As soon as one is sighted, the canoes separate and the net is paid out quickly in a semi-circular manner across the direction of the shoal which gets encircled by the net. Then the crew frighten the fish by making loud noise and by splashing the water; the terrified fish scatter in flight in all directions only to get themselves firmly gilled in the surrounding well or net. The net is then hauled up on board to remove the catch. The fishermen use several combinations of net pieces of different meshes to capture shoals of different size groups thus making the net efficient to meet any situation. It is also the practice, when occasion demands, to join together several units of such nets in a single operation.

The Kantha bale of Mysore coast and the Bangada Jal of Maharashtra are said to be similar type of nets as Ayilachala vala, with the difference that the former are made of hemp and are operated as anchored gill nets unlike the latter. Generally they are set from a single canoe in shallow waters at dusk and anchored in position by heavy stone sinkers tied, one on either side of the foot rope, to prevent it from displacement. The net is hauled up only the next morning and the fish that are gilled are collected.

In recent years these nets are constructed with nylon twine and are comparatively bigger unlike the cotton and hemp nets of former days

in several places. Spherical aluminium or polythene buoys are also frequently used with the nets, replacing the wooden floats. Similarly in the case of gill nets also nylon twine has replaced the cotton twine in the construction of nets in several states. Among bag nets, the Pattenkolli of Kerala is said to be constructed entirely of nylon twine (Antony Raja, 1969). It is thus obvious that a resurvey of the fishing gear presently employed in the mackerel fishery is urgently called for, as it would bring out several additional facts about these gear.

6.1.3 Efficiency and selectivity of gear

Practically no information is available on the selectivity of the various gear that are employed in the mackerel fishery. It may be pointed out, however, that the different types of bag nets and shore seines are non-selective gear due to very little variation in their mesh size (which is normally very small), unlike that of gill nets and drift nets. Even in these latter cases, especially in gill nets, fishermen employ a combination of different mesh net-sections to make the gear efficient to capture a wide range of size groups abundant in the area. The size frequency diagrams given by Rao et al. (1962) for the selective and non-selective gear employed in the mackerel fishery of Mangalore, fully illustrate this point. The difference in the size composition that is observed at times within the bag net and shore seine catches could apparently be not only due to the distribution pattern of different shoals but also obviously due to the differences in the time and the area of operation of these gear themselves. In this connection and also with reference to the selective efficiencies of various gear, the comments of Dutt (1965), on the experimental studies of Joseph and Sebastian (1964) on the performance of sardine gill nets of different mesh sizes, are relevant. Although the requirements for the study of efficiencies of the various gear are quite obvious, we are left with no alternative, at present, except to consider the catch-per-unit effort data of different gear, in a season, in so far as they represent the rough estimates of the respective gears' fishing powers. Such data for the various types of gear employed at Mangalore are published by Rao et al. (loc. cit.). Similar

Table III

Relative efficiencies of different gear employed in the mackerel fishery at Calicut and Mangalore

Name of the gear	CALICUT 1956-57	1957-58	1958-59	Average efficiency	Percentage efficiency	Name of the gear	MANGALORE 1958-59	1959-60	1960-61	Average efficiency	Percentage efficiency
Ayilakolli vala	1.00	1.00	1.00	1.000	100.0	Pattabale	1.00	1.00	1.00	1.000	100.0
Pattenkolli vala	0.00	8.30	0.64	2.980	298.0	Chalabale	0.00	1.24	0.00	0.413	41.3
Paithu vala	0.05	0.01	0.11	0.090	9.0	Kanthabale	0.26	0.11	0.21	0.193	19.3
Ayilachala vala	0.19	0.21	0.08	0.160	16.0	Cast net	0.00	0.10	1.00	0.367	36.7
Arakolli vala	0.12	0.00	0.02	0.047	4.7	Kollibale	..	0.06	0.00	0.030	3.0
Odam vala	0.01	0.03	0.00	0.013	1.3	Idabale	..	..	3.79	3.790	379.0

information for Calicut during the years 1956-'58 is taken from the author's unpublished data. Based on the above data the relative efficiencies of the gear employed are computed separately for the two places and is presented in Table III.

It may be seen from the data given in the table III that the relative efficiencies of the different gear vary between seasons to some extent, with the notable exception of Pattenkolli vala, which is said to have been introduced at Calicut in 1956-57 season. This net surpassed in efficiency the Ayilakolli vala by eight times during 1957-58 season, probably due to availability factor, though in the succeeding season it proved to be only about 3/5 as efficient as Ayilakolli vala. Based on the average efficiencies during the period it may be mentioned that the Ayilakolli vala and Pattenkolli vala are the two most efficient gear among the bag-nets employed at Calicut. The gill net Ayilachala vala has also proved to be an important gear which is about 1/6 as efficient as Ayilakolli vala. It is clear from the data from Mangalore that out of the six types of gear employed in the fishery, the Idabale which was operated only during 1960-61, has proved to be an efficient gear as it was operated during the peak months of a successful season. However, Pattabale is the most important and consistent gear at Mangalore and is the most efficient of the rest of the gear. The average picture, ignoring Idabale, shows that the Pattabale is about 2½ times as efficient as Chalabale and about 5 times that of Kanthabale. The cast net, Debbale, has showed also a good performance, proving 1/3 as efficient as Pattabale. It only remains to be said that, for a study of this nature, the average relative efficiencies of the different gears calculated over a number of seasons should be obtained to make the data more dependable and comparable.

6.2 FISHING AREAS

The fishery for mackerel on the west coast is confined to the area from Ratnagiri to Cape Comorin, while on the east coast the fishing [illegible] [illegible] Orissa coast. On an average, about 93-98% of the total landings come

from the west coast (See table VI of the present report and Pradhan and Rao, 1958). Even on the west coast, intensive fishery is confined to the area from Ratnagiri in Maharashtra down south to Ponnani in Kerala. The important centres on the west coast for mackerel are Malvan, Karwar, Malpe, Bockapatnam, Cannanore, Tellicherry, Calicut, Tanur and Ponnani. The mackerel shoals that appear sporadically on the east coast are exploited at important centres like Mandapam, Nagapattinam, Madras, Kakinada, Pudimadaka and Visakhapatnam.

Depending upon the intensity of fishing, duration and the type of gear employed, the main fishery area on the west coast is divided into the following sub-areas: 1) Ratnagiri-Mangalore area where the catches are highest, 2) Mangalore-Ponnani area where they are relatively high, and 3) Ponnani-Cape Comorin area where the catches are moderate (Pradhan, 1956 and Pradhan and Rao, loc. cit.). The fishery is confined at present to the foreshore area within 18 m depth limit. Although considered as a typical pelagic fishery, instances where mackerel were caught in deep waters by trawls off Bombay-Saurashtra area, Wadge Bank and Bay of Bengal have come to light (Narayanankutty, 1962; Sivalingam, 1955 and Jones and Rosa, 1967). Recent surveys of R.V. VARUNA have also indicated the presence of shoals in waters upto 20 m depth (Jones and Rosa, loc. cit.).

6.3 FISHING SEASON

With the outbreak of the south-west monsoon on the west coast, some shoals comprising younger fish first start appearing in the inshore area followed by shoals of slightly bigger fish. According to Chidambaram & Venkataraman (1946), the fishery on the west coast extends from September to April. At Karwar, one of the important northern centres for mackerel, the fishery starts only by October extending upto February or March (Pradhan, 1956). It is stated by Pradhan and Rao (1958), Jones and Rosa (1967) and Rao (1969) that in general the mackerel fishery starts earlier and lasts longer on the Kerala coast than along the Mysore and Maharashtra coasts. The average monthly landings of mackerel compiled for four centres and presented in the Table IV and also the average quarterly data for different States given in Table V, fully illustrate the situation on the west and east coasts. It is evident from the

table IV that the fishery starts at Vizhingam, the southern-most centre in Kerala, by June extending until October with maximum landings in July. Further north, at Calicut, it starts only by August and extends till the end of March with a major peak in September and a minor one during December. The picture of the fishery at Mangalore, though not quite suggestive of the trends, may be said to be similar to that of Calicut. The picture of the fishery at Karwar, one of the northern-most centres on the Mysore coast, is quite different. Here it starts quite late by October and extends upto April with a major peak in November and secondary one in February, the data in Table V also show the same fishery trends on quarterly basis, along Kerala, Mysore and Maharashtra.

Table IV

Average monthly catch (m. tons) of mackerel at different centres on the west coast

Month	Vizhingam 1960-63 (Bennet, 1967)	Calicut 1956-58 (Unpublished data of Rao, K.V.N.)	Mangalore 1958-61 (Rao et al., 1965)	Karwar 1956-59 (Banerji & Chakraborty 1965)
January	1.62	206.48	1.14	105.92
February	0.42	121.99	3.08	167.93
March	0.55	14.88	6.88	124.01
April	8.68	8.50	3.89	36.66
May	0.23	3.64	1.03	0.00
June	2.85	4.63	0.00	0.00
July	15.30	3.34	0.00	0.00
August	3.83	32.88	20.18	0.00
September	4.46	1221,41	4.38	0.00
October	2.94	148.05	10.21	66.91
November	1.18	92.82	13.69	664.03
December	0.35	385.72	18.29	568.20

Table V

Average quarterly landings (m.t.) of mackerel in different States for the years 1956-1968 (Source: CMFRI Bull.No.13, 1969)

Regions	Quarters I	II	III	IV	Annual catch
Orissa	50.2	8.8	0.8	28.3	88.1
Andhra	554.1	477.1	28.1	330.9	1,390.2
Madras	546.6	607.5	749.9	267.1	2,171.1
Kerala	5,181.8	1,367.0	3,075.5	11,782.8	21,407.1
Mysore	4,214.4	102.4	224.3	20,585.1	25,126.2
Maharashtra	904.8	2.1	6.5	1,949.8	2,863.2

Similarly, on the east coast, the fishing season is much longer on the Madras coast with peak catches occurring during the third quarter. The fishery along Andhra coast is comparatively shorter, starting by the fourth quarter and extending till the end of third quarter, while the peak occurs during the first quarter. The fishery is shortest along Orissa with maximum landings occurring during the first quarter (Table V).

6.4 FISHING OPERATIONS AND RESULTS

6.4.1 Effort and intensity

Although the data on the input of effort in the mackerel fishery and its catch along the various sections of the coast during different fishing seasons are being collected regularly by the Institute and also the trends in the catch-per-unit effort at selected centres on the west coast are studied, we have very little of published information on effort and intensity. The preliminary studies of Pradhan (1956) and the more detailed and systematic studies of Banerji and Chakraborty (1962) from Karwar have given us some insight on these aspects. It is clear from their studies that the distribution of effort and the intensity of fishing is not commensurate with the abundance of mackerel shoals not only within the season but also during different fishing seasons. This situation is brought about, it is explained, not due to the inability of

the fishermen to detect good periods of abundance, but due to economic considerations (Sekharan, 1958 and Banerji and Chakraborty, loc. cit.). But the obvious effect of such a situation is that the fishing tends to be less efficient, thus yielding much less catch than what would be the case had the fishing intensity been increased proportionately during the periods of abundance of shoals in the inshore waters.

6.4.2 Catch

Annual variations: The annual landings of the Indian mackerel in different regions as well as on all-India basis and the species contribution to the all-India marine fish production for the period 1950-63 are presented in the Table VI. From the data the extent of fluctuation in the fishery not only from year to year but also over a number of years is obvious. The average catch for the period under consideration was 58,316 tonnes. It may be seen from the data that the fishery has yielded more than the average catch during the years 1950-1953, 1957-1960 and in 1963; and less than average during the other years. During the periods when more than average yields were obtained, the fishery witnessed over one lakh tons only during 1951, 1958 and 1960 with the maximum of 1,33,655 m.t. during 1960. The trends of catch indicate further that the fishery was declining since 1952 reaching the lowest level of 16,341 m.t. in 1956. Similar trend in the fishery is also evident during the past five years or so. Thus it may be seen that there are short periods of abundance alternating with long periods of decline in the fishery.

The contribution of the mackerel to the all-India marine fish production during the period under review ranges from as high as 19.65% in 1951 to as low as 2.28% in 1956 representing one of the most successful and one of the worst years of mackerel fishery respectively. Though the highest mackerel catch was obtained in 1960, it constituted only 15.19% of the total marine fish catch during that year.

Table VI

Regional and all-India annual landings of mackerel (m. tons) as compared with total marine fish production during the years 1950-1968 (Source: CMFRI Bull. No.13, 1969)

Year	Orissa & Bengal	Andhra	Madras	Kerala	Mysore	Maha-rashtra
1950	-	-	-	-	-	-
1951	-	-	-	-	-	-
1952	-	-	-	-	-	-
1953	-	-	-	-	-	-
1954	-	-	-	-	-	-
1955	-	-	-	-	-	-
1956	17	1,110	1,286	8,986	3,177	1,638
1957	83	1,005	1,400	26,187	55,754	4,576
1958	37	293	393	55,476	65,365	1,707
1959	79	434	975	24,689	29,332	6,675
1960	46	2,862	1,166	35,504	81,882	12,187
1961	22	1,176	5,607	20,044	7,276	55
1962	17	601	3,115	11,938	11,446	1,971
1963	20	1,163	3,095	48,917	19,132	4,645
1964	38	1,898	2,932	9,657	7,263	2,063
1965	538	1,155	521	18,048	18,125	763
1966	23	2,065	1,975	10,747	7,102	175
1967	153	2,062	3,360	4,500	15,050	27
1968	13	2,249	2,400	3,599	5,736	486
Average	83	1,390	2,171	21,407	25,126	2,844
Percentage	0.16	2.62	4.09	40.37	47.39	5.37

Year	Total for East coast	Total for West coast	All-India total for Mackerel	All-India total for All marine fish	Percentage of mackerel in marine fish
1950	-	-	89,163	5,80,022	15.37
1951	-	-	1,04,900	5,33,916	19.65
1952	-	-	78,104	5,28,348	14.78
1953	-	-	70,748	5,81,463	12.17
1954	-	-	28,258	5,88,258	4.80
1955	-	-	22,796	5,95,725	3.83
1956	2,413	14,018	16,431	7,18,779	2.28
1957	2,488	86,522	89,010	8,75,516	10.17
1958	723	1,22,559	1,23,282	7,55,994	16.31
1959	1,488	60,710	62,198	5,84,587	10.64
1960	4,074	1,29,581	1,33,655	8,79,681	15.19
1961	6,805	27,680	34,485	6,83,569	5.04
1962	3,733	25,370	29,103	6,44,244	4.52
1963	4,278	72,702	76,980	6,55,484	11.74
1964	4,868	18,995	23,863	8,59,582	2.78
1965	2,214	40,881	43,095	8,32,777	5.17
1966	4,063	27,896	31,959	8,90,311	3.59
1967	5,575	23,619	29,194	8,62,631	3.38
1968	4,662	16,123	20,785	9,02,948	2.30
Average	3,645	51,281	58,316	7,13,360	-
Percentage	6.64	93.36	-	-	8.17

It may be mentioned that the year-to-year fluctuations in the catch are characteristic of a short-lived species, as is the case with mackerel, where the success or the failure of the fishery depends on the strength of the incoming age class which is dependent on the variations in the recruitment and availability. The underlying causes for the long-term fluctuations in the fishery may perhaps be sought in more basic changes that are likely to have occurred in the environment.

Spatial variations: The region-wise catch data given in Table VI fully illustrate the spatial variations in the mackerel abundance. It can be seen from the data that about 93.4% of the total average annual catch came from the west coast, while the remaining 6.6% from the east coast of India. It is also evident from the catch trends of mackerel on the west coast that the waters off Mysore and Kerala are more productive than those of Maharashtra. These two States together contribute on an average about 90% of the west coast's production. Between them, however, Mysore coast is more productive than Kerala. Similarly, on the east coast, the waters off Tamil Nadu on an average yield twice that of Andhra coast, while Orissa's contributions are an insignificant fraction. The data also show further that the catches decrease from the southern to northern regions on the east coast, while on the west coast the yield is better in the central region of the fishing area off north Kerala and the whole of Mysore than either in south Kerala or Maharashtra coasts.

In order to find out the more productive regions within Kerala and Mysore, the estimated landings at selected centres in the area, where comparable data are available, are summarised from the quarterly and annual reports of the Central Marine Fisheries Research Institute and are given in the Table VII. It may be seen from the data that the mackerel fishery within Kerala yields better catches at centres north of Cochin than at the southern centres. Similarly, within Mysore, where data are available from two extreme centres, the landings at Karwar, the northern-most centre in Mysore, are the highest as compared with Mangalore or, for that matter, any other centre on the Kerala coast. The low yield at Mangalore may be explained as due to the fact that they represent conditions at Ullal, a minor centre, where no Rampan operations were done for mackerel (See Rao et al., 1962). In fact at Malpe,

Table VII

Quarterly and annual landings of mackerel (in m.t.) at selected centres on the west coast (Quart.& Ann.Repts. CMFRI from 1958 to 1966)

Fishing season & Quarter		Vizhingam	Cochin	Calicut	Cannanore	Mangalore	Karwar
1958-59	I	2.68	-	25.78	-	-	0.02
	II	7.51	-	373.70	-	-	0.00
	III	3.26	-	865.91	-	84.40	1441.90
	IV	2.05	-	184.39	-	24.88	1262.50
Total		15.50	-	1449.78	-	*	2704.42
1959-60	I	8.90	-	9.98	-	4.54	38.00
	II	51.01	-	53.70	-	4.64	0.10
	III	5.15	-	361.62	-	9.11	837.11
	IV	1.16	-	45.83	-	1.16	95.99
Total		66.22	-	471.13	-	19.45	971.20
1960-61	I	1.24	-	0.00	0.46	2.00	0.00
	II	28.30	-	169.70	470.74	44.47	0.66
	III	5.78	-	683.04	563.23	33.09	2598.80
	IV	7.07	-	168.24	311.44	5.08	85.10
Total		42.39	-	1020.98	1345.87	84.64	2684.56
1961-62	I	3.23	-	46.46	59.78	8.23	0.22
	II	2.89	-	51.49	9.01	0.00	0.00
	III	5.35	-	353.36	28.91	14.09	50.03
	IV	1.87	-	38.64	1.68	0.00	0.00
Total		13.34	-	489.95	99.38	22.32	50.25
1962-63	I	8.16	0.00	8.17	17.40	0.01	0.00
	II	14.96	86.10	185.78	43.06	0.00	0.01
	III	2.58	5.36	236.56	69.06	72.65	773.00
	IV	1.73	0.00	33.84	9.74	6.94	33.99
Total		27.43	91.46	464.35	139.26	79.60	807.00
1963-64	I	1.17	8.49	4.32	23.47	2.18	0.02
	II	3.24	163.34	1499.01	352.93	14.69	6.21
	III	0.63	38.65	360.54	461.32	30.67	959.37
	IV	0.39	0.79	0.12	102.64	4.97	80.40
Total		5.43	211.27	1863.99	940.36	52.51	1046.00
1964-65	I	0.18	0.80	8.61	54.21	21.59	0.00
	II	16.10	0.75	53.30	8.68	0.00	1.70
	III	5.77	31.03	345.64	157.14	17.10	137.71
	IV	5.20	12.43	97.92	31.15	8.88	552.15
Total		27.25	45.01	505.47	251.18	47.57	691.56
1965-66	I	12.02	6.79	2.98	10.97	4.49	9.41
	II	8.58	17.12	11.29	0.73	2.56	0.33
	III	17.13	35.19	47.25	48.02	11.73	64.38
	IV	5.15	10.35	9.34	13.13	0.80	19.95
Total		42.88	69.45	70.86	72.85	19.58	94.07
1966-67	I	24.20	0.00	2.98	5.03	0.27	0.00
	II	15.31	49.88	444.82	23.33	7.25	0.00
	III	4.54	2.69	303.40	77.42	225.88	1012.31
	IV	0.73	7.01	15.03	12.45	14.75	9.50
Total		44.78	59.58	766.23	118.23	248.15	1021.81

I = April-June, II = July-September, III = October-December, IV = January-March.

* Incomplete.

Table VIII

Quarter-wise landings (m. tons) of mackerel in different States during the years 1956-1968

Years	Orissa I	II	III	IV	Andhra I	II	III	IV	Tamil Nadu I	II	III	IV
1956	0	1	0	16	0	1050	5	55	635	52	427	172
1957	0	0	0	83	93	807	6	99	475	344	527	54
1958	26	0	0	11	116	51	22	104	261	15	93	24
1959	57	11	0	11	57	160	39	178	315	253	275	132
1960	23	10	1	12	2186	146	3	527	396	478	128	164
1961	5	0	0	17	366	745	7	58	289	185	4799	334
1962	1	3	0	13	456	144	1	0	1534	1230	279	72
1963	4	4	0	12	467	78	94	524	126	776	1427	766
1964	29	66	0	3	584	508	95	711	1540	908	458	26
1965	350	7	0	181	108	113	6	928	96	212	36	177
1966	14	0	0	9	422	630	52	961	379	366	610	620
1967	135	8	10	0	967	1018	23	54	530	1874	82	874
1968	8	5	0	0	1381	753	12	103	530	1205	608	57
Average	50	9	1	28	554	477	28	331	547	608	750	267
Percentage	57.0	10.0	0.9	32.1	39.9	34.3	2.0	23.8	25.2	28.0	34.5	12.3

Years	Kerala I	II	III	IV	Mysore I	II	III	IV	Maharashtra I	II	III	IV
1956	740	73	1730	6443	911	56	172	2038	305	15	50	1268
1957	3187	2170	2374	18456	2582	24	434	52714	3388	5	4	1179
1958	13259	3940	3879	34398	10062	111	41	55151	414	0	0	1293
1959	15073	6232	135	3249	18215	385	74	10658	6438	1	1	235
1960	6346	27	4304	24827	4306	0	61	77515	77	0	0	12110
1961	11345	2009	3358	3332	121	26	1	7128	333	0	1	21
1962	1357	274	298	10009	0	0	0	11446	0	0	0	1971
1963	3413	703	16711	28090	837	192	414	17689	42	2	0	4601
1964	1405	1287	1142	5823	1541	527	888	5107	9	1	0	2503
1965	9033	875	255	7885	14980	9	57	3079	754	1	0	8
1966	935	138	3368	6306	840	1	1478	4783	1	0	2	172
1967	[illegible]	[illegible]	2180	11524	249	0	0	14801	1	0	0	26
1968	503	14										
Average	5182	1367	3076	11783	4214	102	224	20585	905	2	7	1950
Percentage	24.2	6.1	14.4	55.0	16.8	0.4	0.9	81.9	31.6	0.1	0.2	68.1

which is situated a little north of Mangalore, the fishery yields quite high catches due to Rampani operations (Sekharan, 1958). Further commenting on the productive areas of mackerel, Pradhan (1956), Pradhan and Rao (1958) and Rao (1969) have stated that the mackerel landings, between Ratnagiri in Maharashtra and Mangalore in Mysore are very high and between Mangalore and Ponnani, the amount of catch is fairly high.

Seasonal variations: The region-wise and quarter-wise data given in Table VIII representing the average picture for the years 1956-68, fully illustrate the trends in the temporal variation of the mackerel catch in the annual fishery. It may be seen that off Maharashtra and Mysore coasts the peak landings occur during the fourth quarter, accounting for 68.1% and 81.9% of the respective State's mackerel catch. In both these States, the fishery maintains a very high yield only during a short period, decreasing thereafter rapidly as it develops during the October-December period. In both the areas the fishery extends till the end of first quarter. On the Kerala coast, however, the landings are more spread out, with the peak catches occurring here also during the fourth quarter forming 55.0% of the State's average annual landings. On the east coast, off Orissa, the fishing season, again, is short with 57.0% of the annual catch in the region coming during January-March months. The data for Andhra and Tamil Nadu show that the mackerel fishery is not only more spread during the year but also the decrease in catches is more gradual, with periods of abundance shifting to later periods depending on the region. Thus along Andhra coast the fishery starts by fourth quarter extending upto the second quarter with peak landings occurring during the first quarter. Off Tamil Nadu, the fishery is more spread out and gradual compared to Andhra, with peak fishery occurring during the third quarter. Of the State's annual catch, the quarterly break-up is 25.18%, 27.98%, 34.54% and 12.30% respectively. It may also be seen from the data that the period of low catch on the west coast is from April-June while on the east coast it is during July-September off Orissa and Andhra regions and during October-December along Tamil Nadu coast.

6.4.3 Factors affecting the fishery

It is well-known that several factors of the environment like the physical, chemical and biological phenomena, operating in a complex manner, would affect the mackerel fishery either directly or indirectly. It is easy to visualize that variations in any one or a set of the above factors could easily influence either the level of recruitment (and hence the abundance) and/or availability of the different age groups depending whether those factors are operating either on breeding and nursery grounds and/or on fishing grounds respectively.

In the past, several attempts have been made to find out simple correlations between some of these physical, chemical and biological factors of the environment and the mackerel fishery in order to explain the observed fluctuations in the fishery. It is stated by Panikkar (1949) that any delays in the onset of monsoons on the Indian coasts are often followed by delays in the fishing seasons for mackerel and oil sardine. Thus the profound influence of the monsoons providing the main motive force for all the dynamical changes in the seas around India affecting the fisheries of the area is obvious, although very little is known about the mechanism by which the fishery is affected in our seas. Chidambaram and Menon (1945) have found from their studies at Calicut that there is a correlation between the fish landings and the environmental factors like rainfall, surface temperature, salinity and specific gravity and of plankton abundance of the area. Theirs and later studies (Bhimachar and George, 1952; Subrahmanyan, 1959; Sekharan, 1958 and Pradhan and Reddy, 1962) have indicated that the peak landings generally occur just during the period when the factors like temperature, salinity and specific gravity of the surface waters start rising in their values after reaching their minima during the south-west monsoon period on the west coast and just coinciding with or following the plankton abundance in the area.

An inverse relationship between the mackerel and the oil sardine fisheries has been observed (Hornell, 1910b, Nair and Chidambaram, 1951 and Antony Raja, 1969). Though this relationship does not appear to be consistent on year-to-year basis, it appears to be so over long-term

basis as is evident from the data presented in Fig. 9. Since both the species are plankton feeders and occupy the same neritic-pelagic habitat, one should expect competition between them both for food and space, thus the abundance and the availability of one species affecting the prospects of the other in a given area. However, the mechanism how it is brought about is not yet satisfactorily explained.

Murty and Edelman (M.S. quoted by Antony Raja, 1969) have indicated a good correlation between the pelagic fisheries in general and mackerel fishery in particular and the sea level pressure differences as an expression of monsoon intensities. They suggested that certain low ranges of monsoon intensities are unfavourable, while certain higher intensities are favourable for the pelagic fisheries, since they found that during the periods of low intensities the surface waters are depleted with dissolved oxygen while at the latter periods it was not so. In a recent study, Murty (1969) has observed that the clue for the seasonal and regional variations in our pelagic fisheries (both mackerel and oil sardine) is to be found partly in the variations in the pattern of the coastal currents, for he found a close correlation between the maximum catches during the winter when the northerly drift currents get established along the west coast and suggests the possibility that the pelagic fisheries of this coast are intimately related to these costal drift currents.

It is also observed that sudden and localized monospecific blooming of several plankters like diatoms, dinoflagellates and blue green algae will adversely affect prospects of a good fishery, since mackerel as well as other pelagic fishes are known to avoid such areas either due to choking of the gills, oxygen depletion caused by death and decay of plankters and due to the effects of ectocrines released by the organisms in the area (Prasad, 1953, and 1967; Bhimachar and George, 1950; and Subrahmanyan, 1954 and 1959).

6.1.1 Forecast

In the case of mackerel fishery no reliable criteria have yet been identified and developed in order to be able to predict the fishery prospects from year to year, although several attempts to link up the fluctuations in the fishery with the environmental factors like temperature, salinity, oxygen and with the plankton abundance over the fishing grounds and with the coastal currents over a wider area have been made. It was also suggested that the fishery is dependent on the strength of the incoming year class and its availability in the inshore area, both of which are subject to variations from year to year, resulting in response to the oscillations in the environmental parameters. In order to find out whether the annual trends in the mackerel fishery themselves would give some insight in the pattern of fluctuations of the mackerel fishery, the available catch data since 1925 to 1968 from the west coast were examined. The data prior to 1948-49 season relate to seasonal catch landed along the Malabar and South Canara coasts, while data for the post-1950 period represent the landings along Kerala and Mysore regions, which are made comparable, after necessary adjustments, with that of pre-1948-49 data. It is thus obvious that the data over the entire period, though not quite comparable in terms of magnitude between the pre-aand post-1950 periods, are considered sufficient for the comparison of the trends in the fishery and are presented in Fig. 9. It may be seen from the data that there are certain definite trends in the fishery - periods of good fishing seasons followed by bad ones,- during the last four and hafl decades. Thus, leaving out the year-to-year fluctuations in the catches, the fishery may be considered to have improved during the periods 1925-32, 1942-46, 1950-53 and 1957-60 which are immediately followed by long periods of failures. The catch data indicate that both within the periods of abundance and decline a cyclical pattern of revival once in every 3-4 year period is discernible. Notwithstanding the limitations of the data examined here, the observed trends, both of short and long-term nature, are indicative of a cyclical phenomenon which, if proved consistent in future based on more reliable and comparable data, offers a simple line of approach for the development of a reliable predictive system.

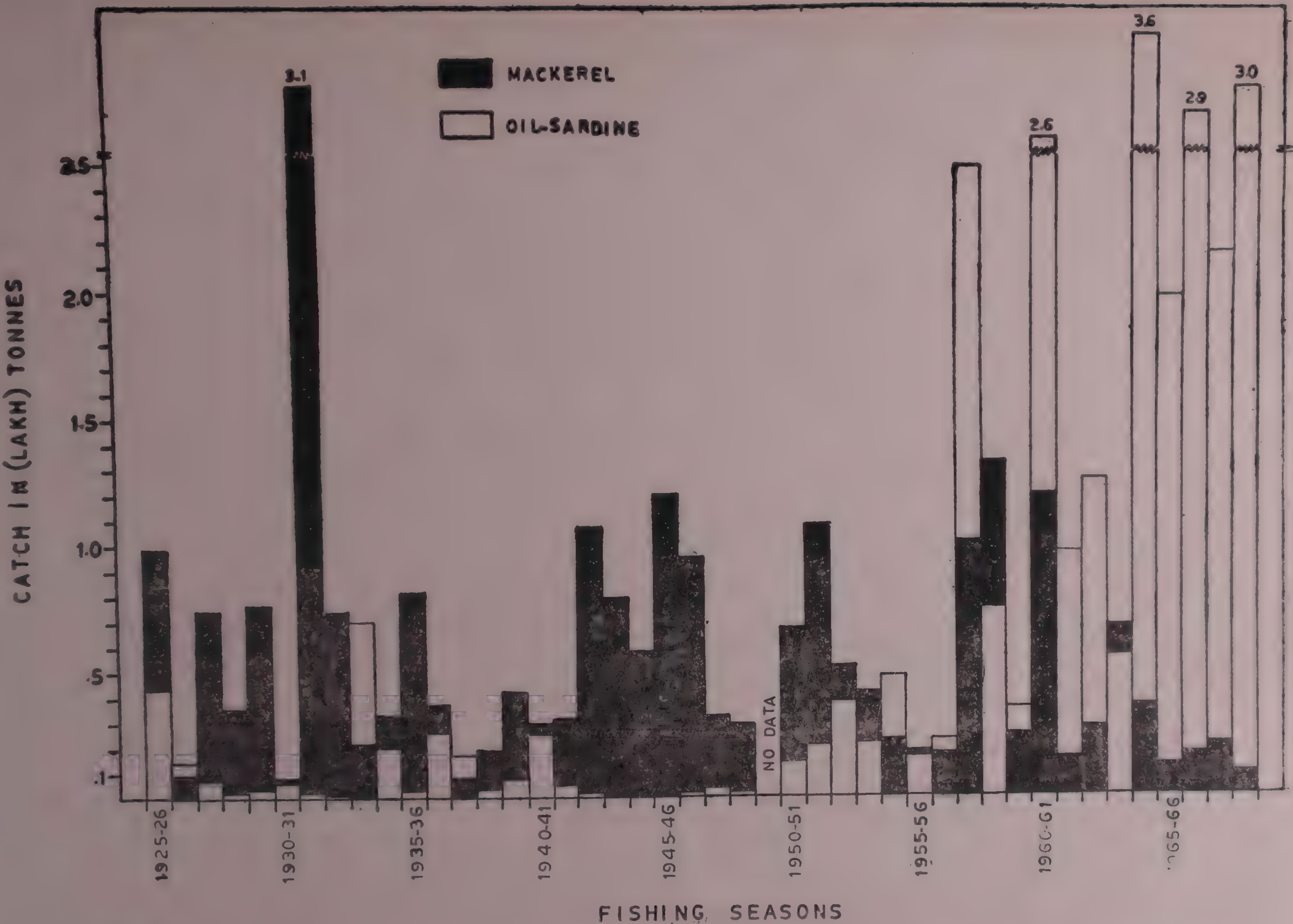

Fig. 9. Trends in the mackerel and oil sardine catch on the west coast (data for pre-1948-49 period relate to Malabar and South Canara regions and for post-1950-51 period relate to Kerala and Mysore coasts).

VII. TECHNOLOGY AND INDUSTRY

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VII. TECHNOLOGY AND INDUSTRY

G. Venkataraman and K.V. Narayana Rao

7.1 CHEMICAL COMPOSITION

7.1.1 Whole fish

The chemical composition of fresh mackerel is reported by Chari (1948) as follows:

Edible portion	61.60%
Water	77.30%
Protein	18.92%
Fat	1.69%
Ash	1.58%
Phosphoras	0.69%
Calcium (Ca O)	0.61%
Iron mg per 100 g	4.45%

Venkataraman and Chari (1951) have given figures of average chemical composition as revealed by analyses carried over a period of 2 years from 1947 to 1949, which are mentioned below:

Water	73.45%
Protein	20.95%
Fat	3.29%
Ash	1.66%

7.1.2 Fish meal

The importance of mackerel fish meal as cattle and poultry feed is well known. It has easily digestible proteins, vitamins and minerals and is obtained by pressing the cooked fish and sun-drying the same. It is also prepared by beach drying i.e. by drying the fish on the beach in the open sun without being cooked. In both cases it is then powdered, sieved, and stored in tins. The composition of mackerel fish meal as worked out by Chari and Pai (1948) and Kamasastry and Rao (1965) is as follows:

Composition	Chari and Pai (%)		Kamasastry and Rao (%)
	Gutted	Ungutted	
Moisture	8.7	8.7	6.3
Protein	68.1	62.1	64.0
Fat	5.8	6.1	6.7
Ash	16.2	20.7	23.8
Acid insolubles	-	-	0.2
CaO	7.9	9.0	9.3
P_2O_5	6.7	6.9	10.7
NaCl	0.3	0.2	-
Insolubles	0.5	2.9	-
Non-protein nitrogen gm	-	-	1.1
Total volatile nitrogen mg	-	-	9.9
Amino nitrogen mg	-	-	77.0
Unidentified	1.2	2.4	-

The chemical composition of mackerel meal as analysed by Negi (1949) is given below:

Moisture	7.81%
Total organic matter	85.48%
Ether extract	5.28%
Carbohydrate	6.76%
Crude protein	73.44%
True protein	71.13%
Total ash	14.52%
Insoluble ash	0.31%
CaO	6.29%
P_2O_5	6.12%
MgO	1.14%
K_2O	0.73%
Na_2O	0.40%
Cl	0.01%

All the above mentioned workers have recorded high food values for mackerel fish meal, specially in protein. Comparatively, the protein value in the sardine meal was found to be low (Nagi, op. cit.). Chari and Pai (1948) found a difference in the protein and ash contents between gutted and ungutted mackerel fish meals. The ash content in the case of ungutted meal showed a higher percentage of insolubles than in the gutted one, probably due to the presence of sand and mud in the food taken by the mackerel. However, they advocate preparation of fish meals from the whole fish, considering the higher percentage of yield in the ungutted fish. Kamasastry and Rao (1965) did not find any appreciable decrease in the protein content of the meal during storage period. It was also observed by them that in the mackerel meal the moisture increased by 50% during the eight months storage period. While there was an increase in the non-protein nitrogen during the storage period, the fall in the amino nitrogen fraction was not quite significant. Venkataraman et al. (1953) observed no change in the moisture content during the storage of fish meals in sealed tins.

7.2 PRESERVATION

7.2.1 Curing

The different methods of curing fish practised along the west and east coasts of India have been given in detail in Agricultural Marketing in India (1951 a & b) and in subsequent publications (Pillai et al., 1956; Pillai and Kamasastry, 1958). There are some valuable earlier accounts by Nicholson (1909), Govindan (1916) and Sorley (1948) on the subject. The former two described the curing industry in Madras State and the latter in Bombay State. Pillay et al. (op. cit.) analysed the chemical composition of the different types of cured samples of mackerel obtained from different places in India. Rao et al. (1958) studied in detail the pit curing methods of mackerel on the east coast of India and found that pit curing improved the "organoleptic properties by imparting a characteristic flavour and softness to the flesh", though their appearance was not favourable and they remained in good condition only for a few weeks after the cure. Investigations relating to dry salting and sun-drying of mackerel with reference to curing of the fish with salts and chemicals and also studies on the storage characteristics and packaging

of sand dried and salted mackerel were carried out at the Central Food Technological Research Institute, Mysore (Sen et al., 1961a; 1961b; 1961c; Lahiry et al., 1961a; 1961b).

Some better methods of curing fish that have been evolved as a result of research done in the recent past are mentioned below: Rao and Sen (1966) have suggested mixing of some chemical preservatives with salts issued to the fishermen for curing, so as to ensure storage of fish in good condition for a longer period. In the case of mackerel they recommend applying 250 kg of common salt, containing 1.25 kg of potassium sorbate, 0.625 kg of sodium benzonate and 3.75 kg of sodium acid phosphate for 1130 kg of whole fish.

An effective but simple method for longer preservation of cured fish with the chemical, sodium propionate, has been evolved by the Central Institute of Fisheries Technology, Cochin. By adding a mixture of small quantities of this chemical in powdery refired salt to the cured fish, it can be kept in good condition free from mould and other visible signs of spoilage up to a period of 9 to 12 months in the case of dry cured product and up to 3 months in the case of wet cured product. By incorporating butylated hydroxy anisole (at 0.5% level) and 0.5% sodium sulphite into the preservative mixture, the onset of rancidity and the occurrence of browning effect respectively can be controlled to some extent (Valsan, 1968).

Pickling of mackerel in brine fortified with 0.5% and 0.25% propionic acid levels has been recommended to keep the fish in good condition for about a year and up to 5 months respectively (Valsan, 1967). Studies on the effect of impurities on the penetration of salt in the curing of mackerel showed that the rate of penetration of salt had no relationship to these impurity contents of salt even at a level of 0.75% (Kandoran et al., 1967).

7.2.2. Canning

Procedures for the canning of mackerel have been worked out by the Central Institute of Fisheries Technology, Cochin and by the Marine Products Processing Training Centre, Mangalore (Fish Technology Newsletter, 5(2), 1964; Rai et al., 1970). Use of enamelled cans with SR lacquers has been suggested for a better presentation of the product. In the

canned mackerel tins, sometimes "curds" are formed, which settle down at the bottom of the can and give an unfavourable impression of the product. Their formation, which is due to the precipitation of soluble proteins in the meat, on heating can be lessened by some methods like "selection of fresh material, proper handling, correct brining and pre-cooking" (Rai et al., op. cit.).

7.2.3 Spoilage

Venkataraman and Sreenivasan (1952) made a study of the bacteria causing spoilage on mackerels and isolated 81 strains of bacteria from the slime, gills and guts of mackerel and also whole and putrid fish. Spore-forming bacillus species formed the majority. The same authors (1953) also observed spoilage of mackerel in oil similar to 'sulphide stinker' caused by a bacterium belonging to the genus Clostridium, the source of which is suspected to be in the guts of mackerel.

Recent researches show that spoilage in mackerel takes place quickly as it contains more enzymes than other fishes and methods have been suggested to prevent it. A generous use of ice in transport, and while in storage and also quicker handling at the processing plants are recommended (Rai et al., 1970). It has been found that mackerel undergoes rapid deterioration even after irradiation, even though they may be free of bacteria. The enzymes present in mackerel cause the spoilage and hence they have to be inactivated by hot water or steam blanching before irradiation, so that the product may have the desired storage of life (Govindan, 1969).

7.3 FAT CONTENT

The variation in the fat content of mackerel of different sizes and in different seasons and its correlation to the food available in the environment, intensity of feeding and state of maturity have been studied (Venkataraman and Chari, 1951 and Chidambaram et al., 1952). Venkataraman and Chari (op. cit.) have reported that while the tendency of ash and protein content of mackerel is to remain constant, the water and fat components are subject to seasonal variation and have a reciprocal relationship. They further observed that the fat contents in mackerel rise to a maximum between September to November and fall thereafter gradually.

Chidambaram et al. (1952) found that mackerel of larger sizes show greater percentage of fat than the smaller ones (less than 16 cm), as shown in the following table, wherein the average value of fat content for different months for whole fish and flesh are given.

Months	Sizes less than 16.0 cm				Sizes more than 16.1 cm			
	Whole fish		Flesh		Whole fish		Flesh	
	Wet %	Water free %	Wet %	Water free %	Wet %	Water free %	Wet %	Water free %
August	1.87	8.00	1.36	5.78	3.47	12.65		
September	1.13	4.70	1.53	5.90	3.96	11.94		
October	-	-	-	-	7.58	25.14	3.85	13.37
November	1.49	6.10	0.93	3.80	8.12	22.19	4.04	14.36
December	-	-	-	-	5.57	19.72	2.74	10.38
January	-	-	-	-	6.96	24.14	2.32	8.78
February	-	-	-	-	6.43	23.77	1.95	7.81
March	-	-	-	-	3.91	14.19	2.96	10.78
April	-	-	-	-	4.60	16.19	4.15	15.73
May	-	-	-	-	4.06	14.02	2.88	10.80
June	1.14	4.22	0.69	2.86	-	-	-	-
July	0.82	3.80	1.00	4.37	3.06	10.23	-	-

The summary of their findings is as follows. The fat contents are at the maximum twice in a year viz. October-November and March-April. In the former period, 16 to 20 cm size group predominates in the catches while in the latter period the fishery is comprised of size group 20 cm and above. In both the periods the fatty condition is attributed to their intensive feeding on the plankton which is abundant in the respective months. The heavy accumulation of fat during March-April period is for building up reserve energy for the purpose of spawning which follows immediately, when feeding is very much restricted. The fish becomes lean after spawning. The fat in immature ones (16.0 cm and less) never rises above 3% in flesh whereas in the mature ones it is as high as 8.5%. The corresponding figures for the whole fish are 2.32% and 12.5%. A great range of variation in the fat content has been noticed in respect of sexes and gonads at different stages of maturity.

Venkataraman and Chari (1953) made estimation of fat in the plankton and correlated it with the fat in the muscle of the mackerel and also in the whole fish. Their observations confirmed the findings of Chidambaram et al. (1952) that the fat contents are at the maximum in October-November and March-April. They noted that the plankton during the period was fatty enough to be correlated with the fattiness of the fish, even though the peak of fat in the plankton was during February and May. They attributed the high fat content in March-April and October-December to the mackerel's intense feeding on plankton rich in fat.

7.4 OTHER CHEMICAL STUDIES

The composition of fatty acids in phospholipids and neutral lipids of mackerel was worked out, the details of which are given below (Fishery Technology Newsletter, 9(1), 1968):

	Palmitic acid	Stearic acid	Oleic acid	Eicosa-pentaenoic acid	Docosahexa-eonic acid
	as mole per cent of methylesters				
Phospholipids of mackerel	19.3	15.7	20.0	5	17.5
Neutral lipids of mackerel	24.3	5.8	12.2	8.6	Traces

Chemical tests on the keeping quality of some important fishes showed that the approximate shelf life in ice storage of mackerel is 14 days and this can be extended by about another 5 days by dipping the specimens for 10 minutes in 50 ppm chlorotetracycline before being stored in ice (Fishery Technology Newsletter, 3(1)).

7.5 UTILISATION

7.5.1 Fresh

Though in the past, more than half of the mackerel catches used to be salt-cured by the dry and wet process or pickled according to Colombo method, in recent years the consumption of mackerel in fresh condition has greatly increased owing to the provision of better transport and preservation facilities. The construction of a large number of ice plants and laying of feeder roads have opened the interior markets,

thereby vastly enlarging the scope for marketing fresh fish in the hitherto inaccessible areas. The value of mackerel has also been rising in the last few years, as could be seen from the value per tonne of mackerel shown below from 1960-61 onwards calculated from the figures in the Administrative Reports of the Fisheries Department, Kerala.

Year	Value per tonne in rupees
1960-61	185
1961-62	343
1962-63	281
1963-64	284
1964-65	303
1965-66	429
1966-67	473
1967-68	604

It is noted that the value has more than trebled over a period of eight years and this can be attributed to two factors, one being the general rise in prices of all commodities due to inflation and the other being the poor catches of mackerel.

7.5.2 Cured

Cured mackerels used to be exported mostly to Ceylon. However our export of dried fish to Ceylon considerably declined from 25,932 tons valued at Rs.4.43 crores in the year 1959 to 5,102 tonnes valued at Rs.1.32 crores during 1968-69. Though efforts were made to encourage exports of dried fish, they did not appear to have been met with success for various reasons. The internal demand for fresh fish increased with the provision of more and more ice and cold storage facilities. Further mackerels became scarce because of the poor catches in recent years barring some exceptions.

7.5.3 Canned

It is estimated that only 0.6% of the total fish catch in India is canned. Canning of mackerel and oil sardine was attempted by the Madras Government at Chaliyam, near Calicut in the earlier half of this

century, but it proved to be a commercial failure due to many practical and technical difficulties. In the recent past, entrepreneurs, realising the vast scope in the seafood canning industry, have started canning factories at Calicut, Cochin and Malpe where sardine and mackerel are canned to a limited extent. Though mackerel is very suitable for canning, only negligible quantities are tinned, the bulk of which goes to the defence services. The various handicaps facing the industry are the lack of regular supply of fish, high cost of tins and the groundnut oil. If the cost of production can be brought down by making available tins and groundnut oil at concessional rates to the industry there are immense possibilities to develop the market for them not only in India but also abroad, thereby earning valuable foreign exchange.

VIII. CONCLUSIONS

By

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VIII. C O N C L U S I O N S

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From what has been stated in the preceding chapters, it may be clear not only how important is the fishery of the mackerel to the Indian fishing industry, but also how varied and elusive are the facts about its biology, life-history and behaviour, upon the knowledge of which depends the success of all fishery management policies. In the light of an objective assessment of the results so far obtained, a multitude of problems for which adequate solutions are yet to be found suggest themselves, as detailed hereunder and these need consideration in our immediate and future programmes of work.

Identity: Since the first description of "kanagurta" by Russell in 1803 followed by the adoption of the bionomial nomenclature, viz. Scomber kanagurta by Cuvier in 1817, the Indian mackerel from almost all over the Indo-Pacific région has been studied in detail under varied synonyms by different taxonomists; Rastrelliger kanagurta (Cuv.) by which valid name it is now known is undoubtedly a recognisable species, distinct from other mackerel species. The study of the variability of some morphometric characters and meristic counts in the Andaman mackerels (Jones and Silas, 1964b) has enabled establishing statistically significant differences between R. kanagurta and R. brachysoma, but we do not know as yet the racial distinctions within R. kanagurta supporting regional fisheries on our coasts. Because of the larger size and distinctive colouration of the Andamanese mackerel, Day (1878) states that it appears to be different from the species occurring along the coasts of the mainland, but it is not known whether the former comprises a distinct race. In the fishery biological studies it is imperative to have a knowledge of the identity of the stocks entering the exploited fishery. Racial studies had been attempted in India and the Philippines, but the results obtained have not been conclusive (Jones and Rosa, 1965). Work in this direction has to be well-planned and re-started.

Another point to be borne in mind in respect of the taxonomic studies is that it is not unusual to find along with Rastrelliger landings, particularly in the east coast of India, a few stray ones of a highly variable Scomber sp. Some of the individual members of the latter are so like R. kanagurta that when one is dealing with large samples, one is likely to miss their identity. This leads to the need for careful examination of Scomber whenever it occurs in the fish catches to find out such characters which would readily be helpful in its field identification.

Distribution: The distribution of the species under the genus Rastrelliger is within the tropical West-Indo-Pacific, coinciding with the Indo-Pacific equatorial current regions which are characterised by high water temperatures on the surface not falling below 17°C in any part of the year, predominant east-westerly surface currents, medium organic production and low degree of seasonal variations. These regions in general show the presence of reef-building corals and rich fish fauna in numerical abundance of the species. The regions where Rastrelliger species occur are divisible into monsoon regions and the north and south equatorial current regions. Regarding distribution of the mackerel supporting fisheries along our coasts, we are concerned only with the monsoon regions of the Arabian Sea and the Bay of Bengal. These regions have relatively large continental shelf; are subject to monsoon winds; have surface currents changing with the monsoons; show the presence of subsurface O_2 minimum layer and medium to high precipitation and run off (Jones and Rosa, loc. cit.).

Regarding differential distribution of eggs, larvae, juveniles and adults some points call for attention. Delsman (1926) recorded the presence of the eggs of R. kanagurta from the Java Sea, but subsequently (1931) doubted their identity. Some of the Indian workers cited in the text had referred to the presence of the mackerel eggs in the plankton collections, but in the absence of descriptive accounts, confirmatory evidence is lacking. Some of the larval stages of mackerel are also on record; Peter (1967b) figured and described some early stages of Rastrelliger, in all probability referable to R. brachysoma. Descriptions with diagnostic characters are lacking here too, as in the case of the eggs.

Fairly detailed information is available on the seasonal and regional occurrence of the juveniles and adult mackerel in the commercial catches

all along the coasts, but here again our knowledge is restricted to the periods of their occurrence in the narrow strip of the inshore traditional fishery zone upto about 25 metres of depth in the neritic waters. What may be the extent of their distribution in deeper waters beyond the known fishing grounds is not known, although occasionally mackerel have been caught in trawls operating in fairly deep waters. Information regarding the oceanic phase of its existence is very desirable.

Reproduction: The Indian mackerel is normally heterosexual although hermaphrodite individuals have occasionally been observed. The size at first sexual maturity as recorded by different workers is between 19 cm and 22.4 cm with the majority of the observations falling at about 22 cm of length.

A careful scrutiny of the recorded observations on spawning periodicity of the mackerel indicates that, taking the west coast region as a whole, the spawning period is spread over the entire year with some regional differences and peaks in certain intervals of time. Thus along the South Kanara coast Sekharan (1958) has reported spawning taking place from March-April to October; Observations at Karwar indicated the possibility of spawning between May-June and January or February; Rao (1965) reported October to end of February being the spawning period of mackerel from Vizhinjam. In general June to August appears to be the peak spawning period on the west coast followed by a minor one in October-November. The main peak period coincides with the south-west monsoon period. Observations recorded on the mackerel of the east coast are fewer, but they indicate a peak spawning in November-December corresponding to the north-east monsoon period, followed by another peak in about March-April. This wide diversity in spawning periodicity probably indicates that the regional fisheries are supported by distinct populations. Although it is known that the spawning is at different times, the extent of variability has not yet been ascertained.

From the occurrence of early juvenilesstages and also such larval stages as have been tentatively referred to the mackerel, some information is available on the likely spawning grounds on the east and west coasts of India. Exploratory spawning surveys are urgently needed, for it is on the basis of this information only we will be able to categorically state the source from which the recruited stocks originate. First and foremost

requirement is the knowledge of the planktonic eggs. Possibly artificial fertilization of the eggs may be successful, if tried on board the exploratory vessel when ripe females with oozing gonads are obtained in the research cruises. When planktonic eggs are obtained in the exploratory surveys conforming to the artificially fertilized eggs, it may be possible to find regional differences if any in the spawned out eggs.

It is unfortunate that no detailed accounts on the fecundity of the mackerel are available in the published literature. The only reference published three decades ago, as referred to in the text, gives an estimate of an average of 94 thousand eggs. A good deal of work still remains to be covered on this aspect of study. It is necessary to know the fecundity in relation to the length/weight of the fish, size and weight of gonad, and frequency of spawning. A detailed investigation may throw light on the structure of the population, if there be more than one constituting the regional fisheries.

Age and growth: Diverse have been the views expressed by different scientific workers on the growth studies of the mackerel. Only a precise knowledge on age in relation to size will enable us to understand the structure of the population and the fluctuation in fishery yields from season to season or year to year. Confirmation of one or the other of the views expressed by different workers in regard to age is possible only when we have sufficient data from the recoveries of the tagged fish. Tagging experiments have been in progress for some years, but the results obtained so far are not conclusive and hence it is needless to say that this programme of work has to be greatly intensified. The size frequency studies on age and growth have been verified in a few instances with growth checks on scales, but such studies have not been extended to similar checks on skeletal structures as the otoliths, centra of the vertebrae, opercular bones etc.

Food and feeding: Fairly intensive studies have been made on the food and feeding habits of mackerel. In general it may be stated that the fish is a planktonic feeder, feeding to a greater extent on zooplankton and comparatively to a lesser extent on the phytoplankton. Mackerel is known to take the bait from the hooks and mackerel stomachs have occasionally revealed whole fish as *Anchoviella* of fair size. It is not as yet known at

what phase of life and what environmental conditions, there is deviation in the normal mode of feeding in the mackerel. At present our knowledge of the food and feeding of the mackerel is confined to the period of its sojourn in the inshore waters, but in its circuit when it leaves the inshore belt and enters the offshore waters, what may be its usual food and at what depth it feeds is little known.

Population: The need for stock assessment and identity of the stock or stocks entering the regional fisheries has been stressed in the chapter dealing with the subject. The annual yields are subject to very great fluctuation, which are characteristic of the single species fisheries. What is urgently needed is a statistical system which enables us to forecast the fishery sufficiently in advance and with reasonable accuracy. Several scientific workers have pointed out the inverse relationship between the mackerel and the oil sardine fisheries. Attempts have been made to ascertain statistically whether there is any positive or negative correlation between the two fisheries. The approach to the problem should be more from the biological point of view. Attempts have been made to understand the behavioural differences and diversity in food requirements between the two species, but the results have not been conclusive.

Exploitation and utilization: The mackerel fishery has so far been an inshore seasonal fishery, exploited by fishermen using indigenous craft and gear, within the narrow coastal belt of about 10 miles in width. Some of the fishing gear like the 'Rampani' is extremely efficient in capturing huge shoals when sighted. The 'Ailakolli' and 'Ailachala' are also efficient in capturing even small shoals. Purse seining by powered fishing vessels is coming into vogue with some success, but only to a limited extent owing to non-availability of the powered vessels, gear and technical know-how. Although much of the catch is being handled making use of the time-old practices of sun-drying, wet curing and pickling, a fair portion is chilled and transported to distant market and also processed by highly refined techniques of freezing and canning.

With progress in biological researches, we are coming to know more and more about the mackerel species and its relation to the regional fisheries on the west and the east coasts of India and also along the coasts of other regions of the Union Territory. Since the mackerel

supports fisheries of importance along the coasts of several South East Asian countries and the research problems being similar, it is desirable to have periodical discussions among scientific workers at international level arranged by World Organisations like the FAO.

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Note. References given under synonyms in the Identity chapter are not listed here. The year given within brackets refer to the year of the journal.